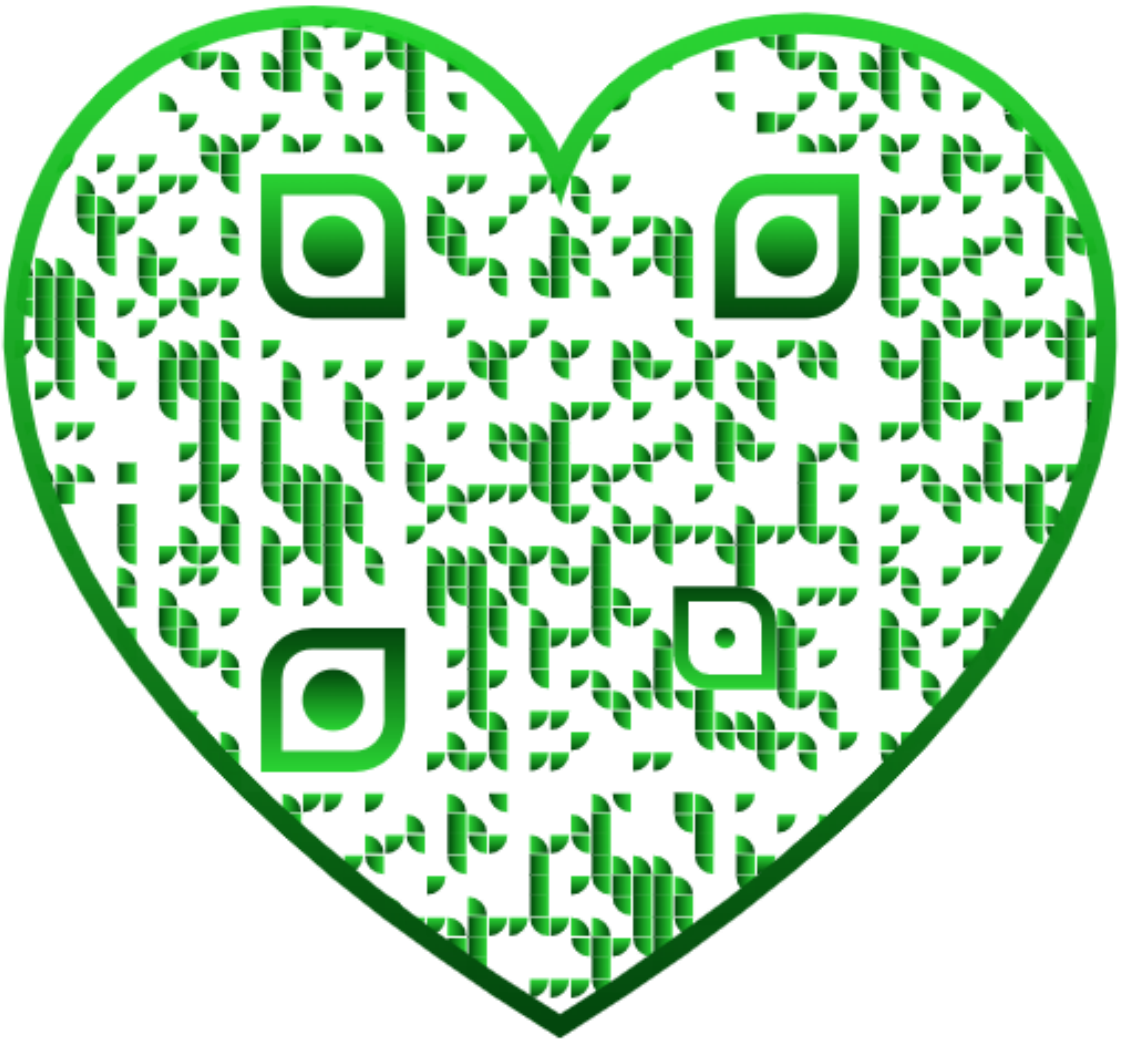
Amino acids, peptides and proteins



I. Amino acids

I.1 General introduction

A. Definition and description of amino acids

❖ **Definition**

➢ aas are organic cpds containing one or more amino groups and one or more carboxylic acid groups.

- so called because they have both amino and acid groups in the same molecule.

Amino acids cont.

- **Importance**: aas are
  - constituents of structural and enzymatic proteins.
  - precursors of a large variety of secondary metabolites:
    - amines, short chain acids, glucosinolates, alkaloids and following deamination-phenylpropanoid compounds.

Amino acids cont.

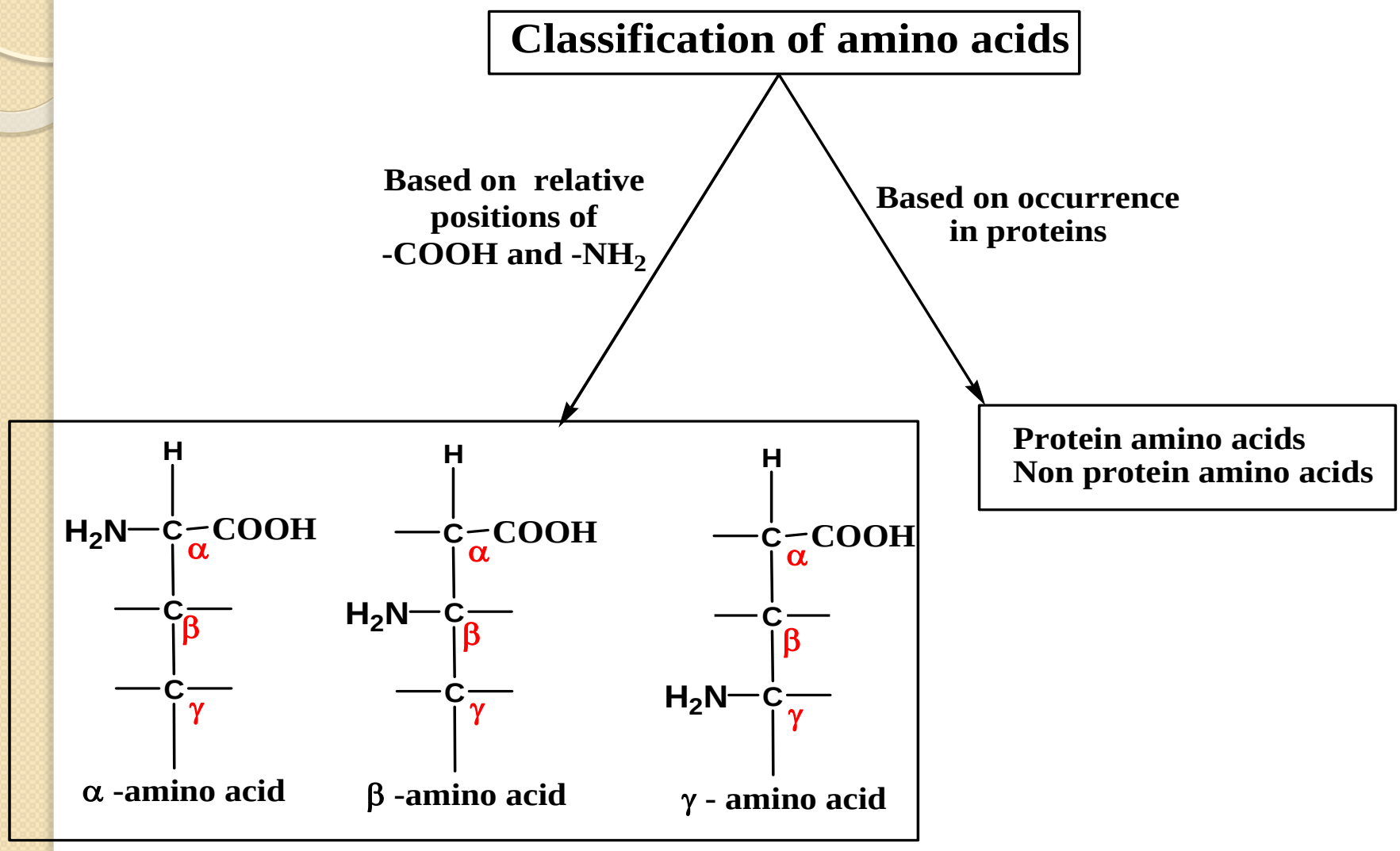
- **Occurrence** -there are several hundreds of amino acids.
  - Most of those found in nature are α-amino acids
  - Some 20 different ones have been isolated from proteins
  - Other amino acids occur in the free-state

Amino acids cont.

- Many aas contain only C, H, O and N, but other atoms may be present
  - e.g. sulphur in cystine, and iodine in thyroxin
- More than one amino group (e.g. lysine) and carboxylic acid group (e.g. aspartic) may be present.

Amino acids cont.

B. Classification



Amino acids cont.

C. Stereochemistry of amino acids:

- The usual notation for assigning configuration to chiral aas is the "D" or "L" notation although the "R' or "S" notation can also be used.
- All naturally occurring proteins contain only "L" amino acids although naturally occurring "D" amino acids are known.

Amino acids cont.

D. Acidity & basicity of amino acids

- aas are amphoteric,
  - i.e., they contain both an acidic portion and a basic portion.
- There is a pKa value associated with
  - the acid strength of the carboxylic acid.
  - the acid strength of the ***conjugate acid of the amine***.

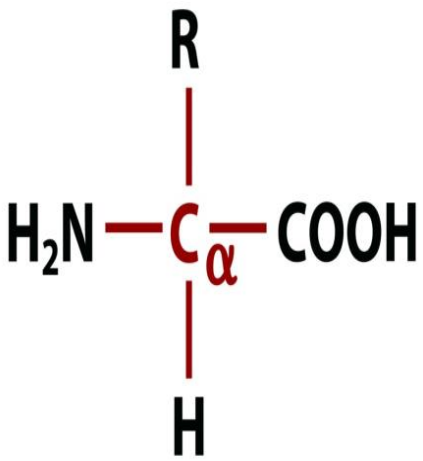
Amino acids cont.

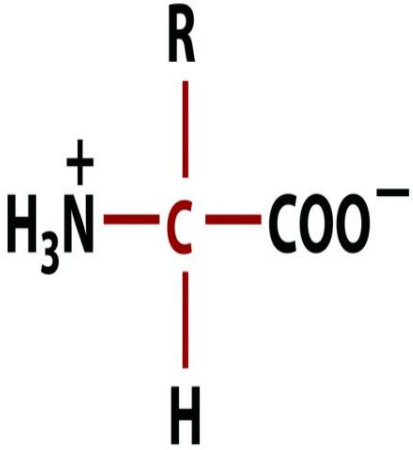
- At certain pH values, aas exist as zwitterions,
  - i.e., as the conjugate acid-conjugate base of their corresponding carboxylic acids and amines.
  - The pH at which the zwitterion concentration is the highest is called the ***isoelectric point***.

1.2 Protein amino acids

1.2.1 Structure and nomenclature

- There are 20 aas that are
  - very important in chemistry and biochemistry
  - used to synthesize proteins
  - all are α- aas with the following general structure:





R – Can be a series of functional groups

Protein amino acids cont.

- Fundamental structural features of α-amino acids
  - Each aa consists of a carbon atom to which is attached
    - -H, $-NH_2$, -COOH and
    - one of 20 different 'R' groups (side chains)
    - The R group
      - Determines the identity of an aa and its special properties

Protein amino acids cont.

- However, proline has an unusual ring structure, where the side chain is bonded at its terminus to the main chain nitrogen.
  - Proline, is a five-membered secondary amine, with N and the α C part of a five-membered ring

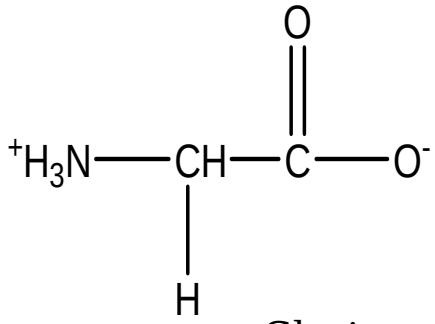
Protein amino acids cont.

- The 20 d/t α-aas are usually named by their common names
- Especially when they are components of proteins, they are usually referred by their three letter or one letter codes
- Their names, structure, three letter code and one letter code are given below

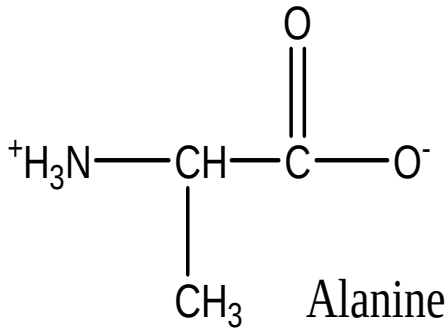
Protein amino acids cont.

- The 20 different amino acids are: alanine (Ala, A), arginine (Arg, R), asparagine (Asn, N), aspartic acid (Asp, D), cysteine (Cys, C), glutamine (Gln, Q), glutamic acid (Glu, E), glycine (Gly, G), histidine (His, H), isoleucine (Ile, I), leucine (Leu, L), lysine (Lys, K), methionine (Met, M), phenylalanine (Phe, F), proline (Pro, P), serine (Ser, S), threonine (Thr, T), tryptophan (Trp, W), tyrosine (Tyr, Y) and valine (Val, V). (Structure: Fig 1.1)

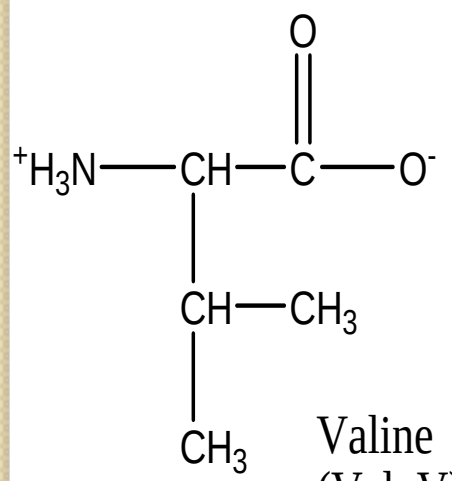
Amino Acids with Aliphatic Side-Chain



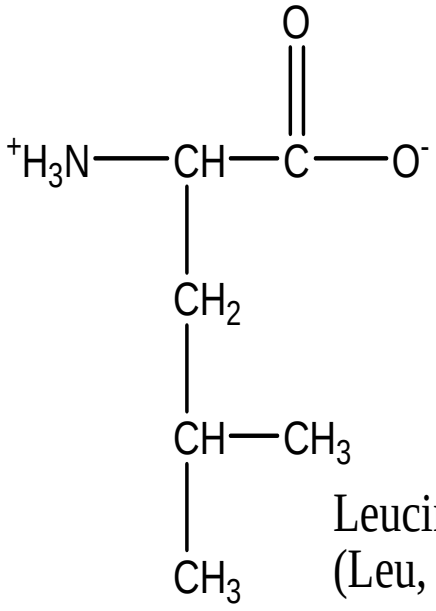
Glycine
(Gly, G)



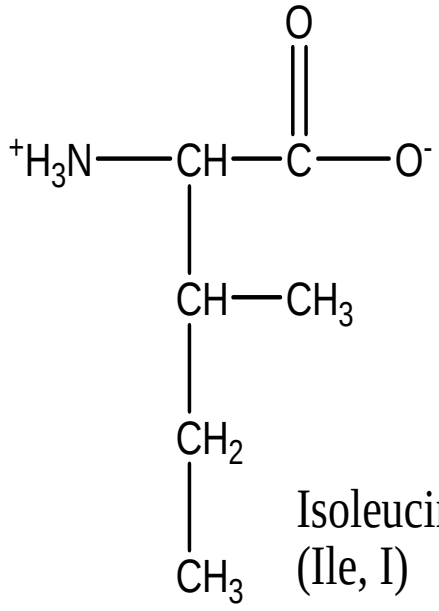
Alanine
(Ala, A)



Valine
(Val, V)

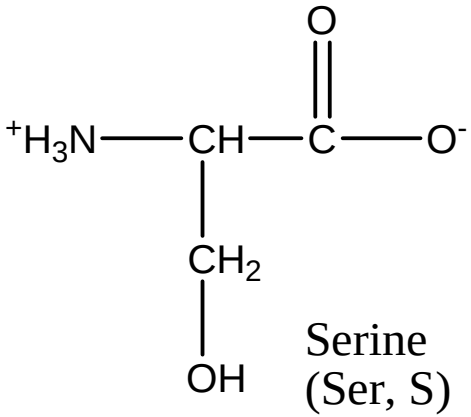


Leucine
(Leu, L)

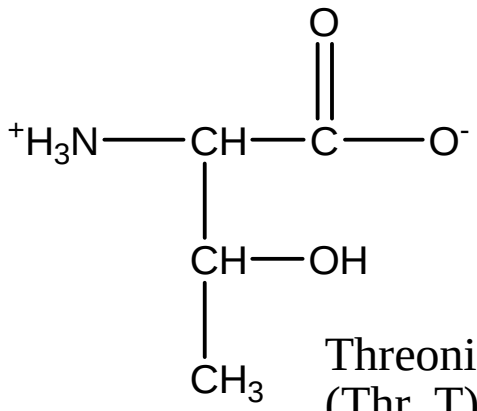


Isoleucine
(Ile, I)

Hydroxy-Containing Amino Acids

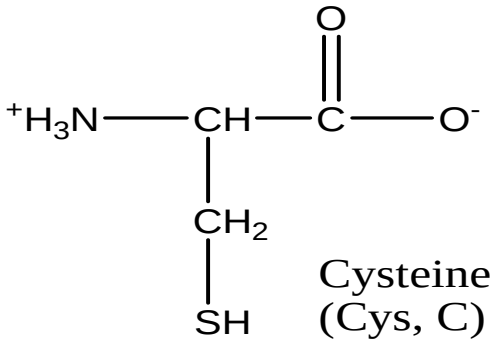


Serine
(Ser, S)

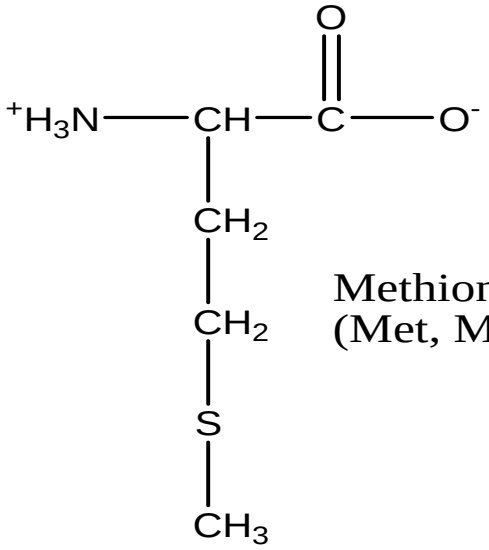


Threonine
(Thr, T)

Sulfur-Containing Amino Acids

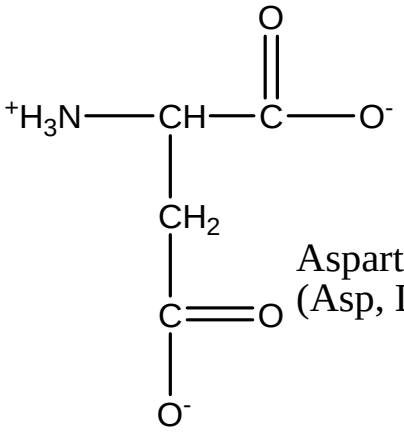


Cysteine
(Cys, C)

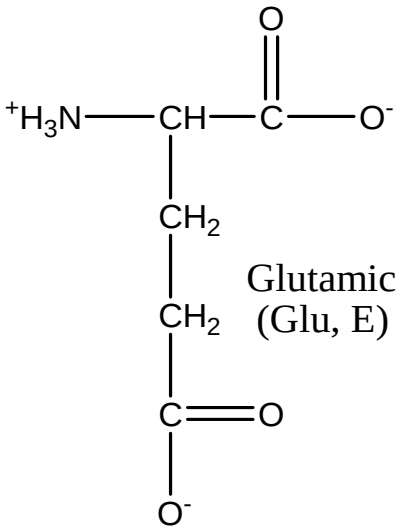


Methionine
(Met, M)

Acidic Amino Acids

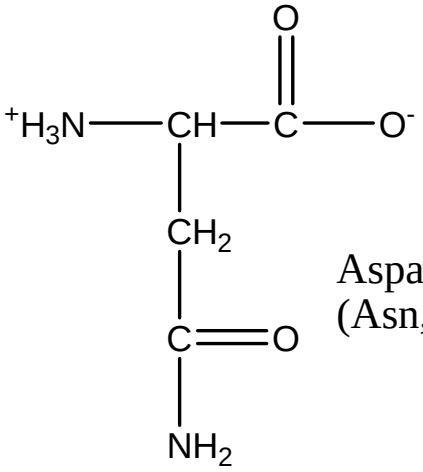


Aspartic acid
(Asp, D)

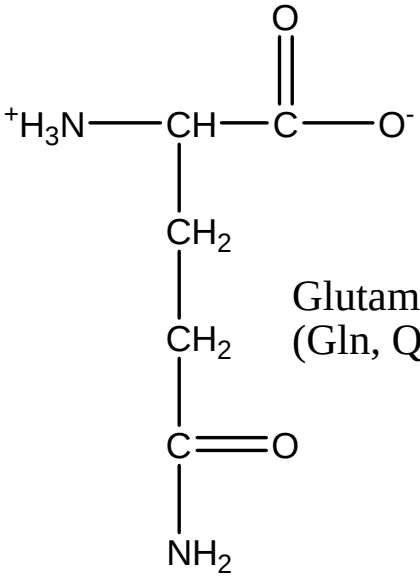


Glutamic acid
(Glu, E)

Amides of Acidic Amino Acids

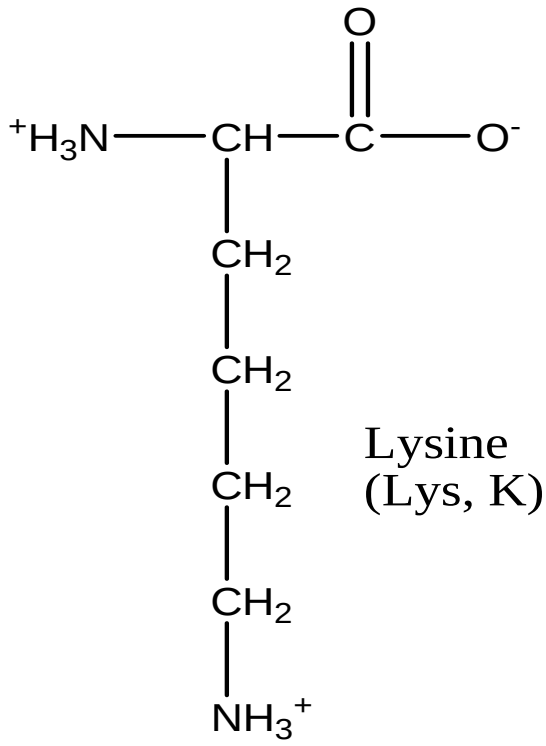


Asparagine
(Asn, N)

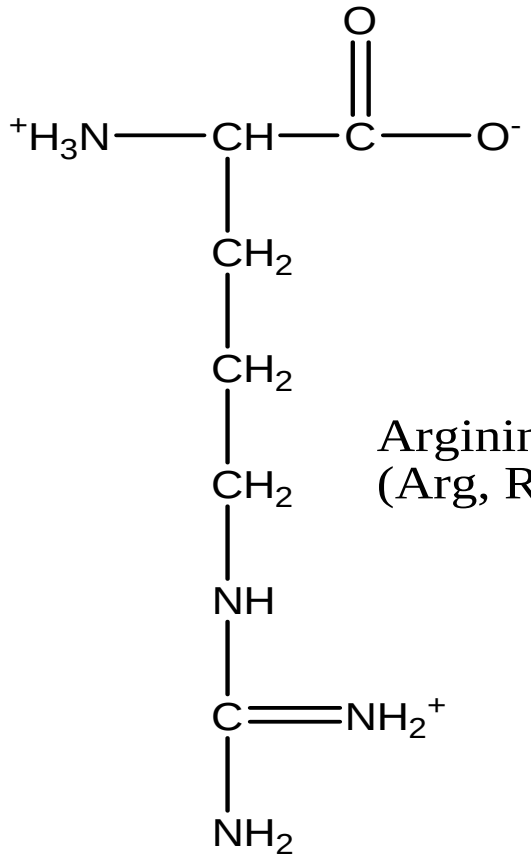


Glutamine
(Gln, Q)

Basic Amino Acids

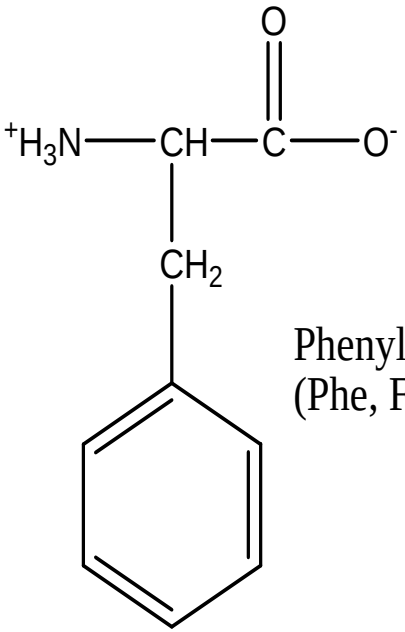


Lysine
(Lys, K)

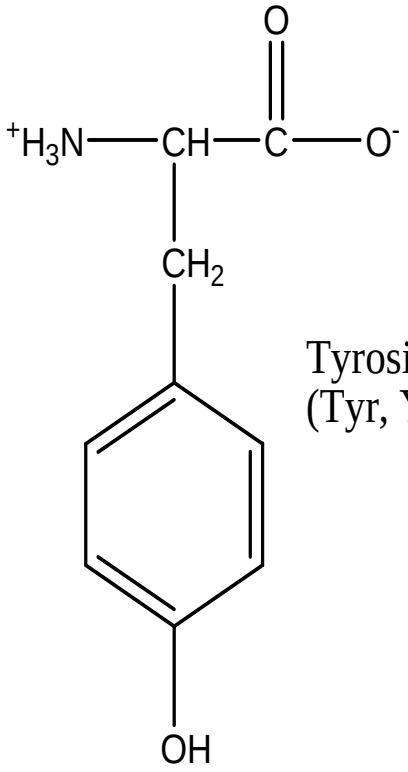


Arginine
(Arg, R)

Benzene-Containing (aromatic) Amino Acids



Phenylalanine
(Phe, F)



Tyrosine
(Tyr, Y)

Heterocyclic Amino Acids

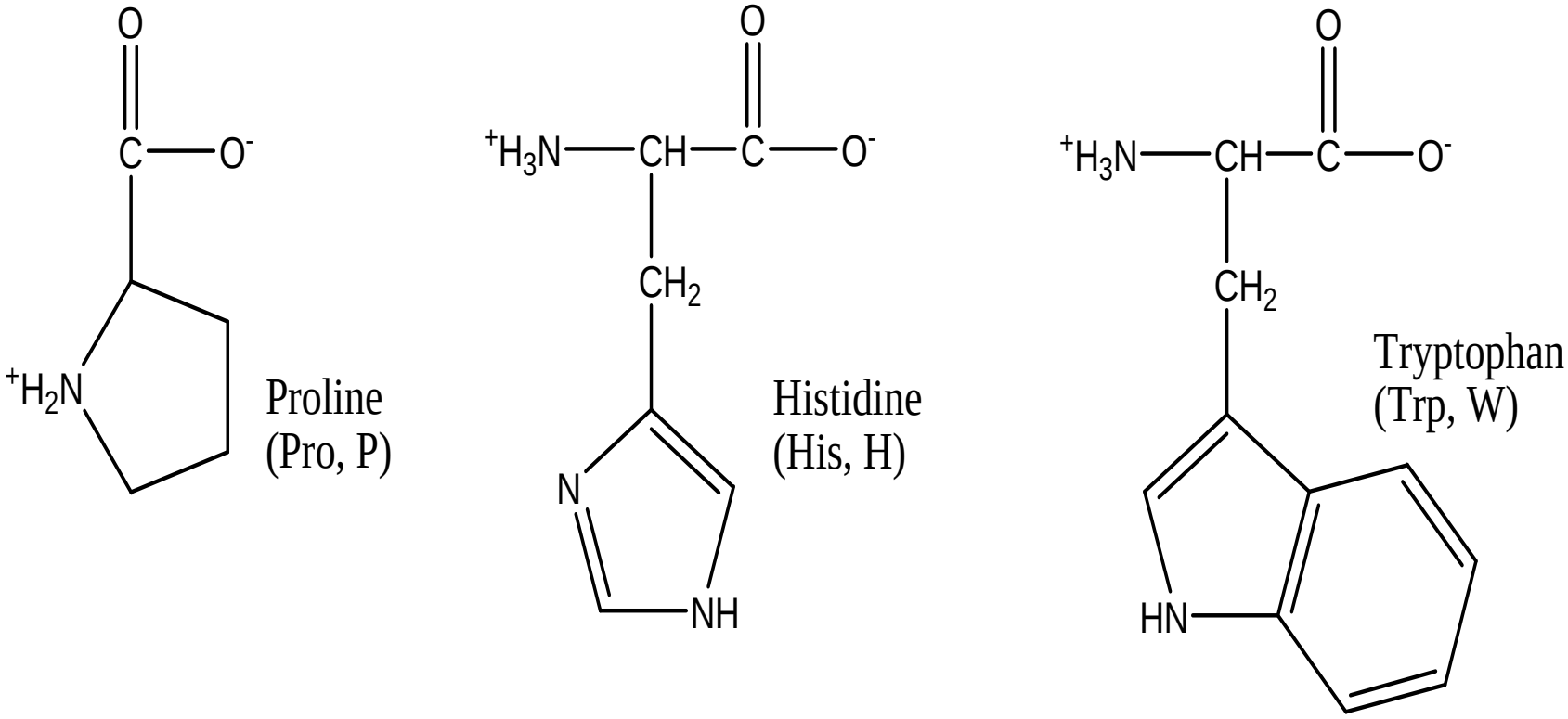


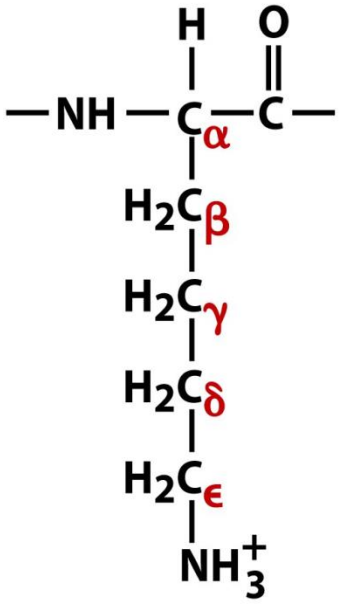
Figure 1.1: structures for the 20 α- amino acids

Protein amino acids cont.

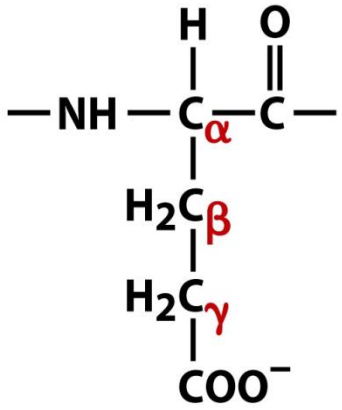
-Greek alphabet or nomenclature: α,β, γ,δ, ε ... is used to indicate location of functional group of side chain; e.g in lysine and glutamate

Greek alphabet

α	alpha
β	beta
γ	gamma
δ	delta
ε	epsilon
ζ	zeta
η	eta
θ	theta
ϕ	phi
χ	chi
ψ	psi
ω	omega



Lys



Glu

Greek lettering used to identify atoms in lysine or glutamate

Protein amino acids cont.

1.2.2 Classification of α- amino acids

- α- aas can be classified in d/t ways:

1. Based on acidity (ratio of amino-group to carboxylic group)
   - neutral/ acidic/ basic aa
2. Based on whether or not containing phenyl group
   - aromatic / non aromatic aa

Protein amino acids cont.

3. Based on nature of side chain

a. Polarity of side chain

- polar / apolar (non-polar) side chain aa

b. Functional group of side chain

- Aliphatic/Aromatic/Acidic/Basic/Hydroxylic/Sulphur-containing/Amidic aa

4. Based on nutrient value to human

- Essential and non-essential

Protein amino acids cont.

1.2.2.1 Types of side chains: acidity

- Neutral: 15 of the 20 have neutral side chains
- Acidic: Asp and Glu have a second COOH and are acidic
- Basic: Lys, Arg, His have additional basic amino group side chains
  - Note: the N in tryptophan is a very weak base

1.2.2.2 Types of side chains: aromaticity

- Only 3 of the 20 aas are aromatic:
  - ✓Phenylalanine, tyrosine, tryptophan

Protein amino acids cont.

- Aromatic aas absorb light in the near ultraviolet (230-300nm).
- Note:
  - UV absorption property of protein is solely determined by the content of these 3 aromatic aas.
  - However, far UV (190nm) absorption of protein stems from the peptide bond.

Protein amino acids cont.

1.2.2.3 Types of side chains: polarity

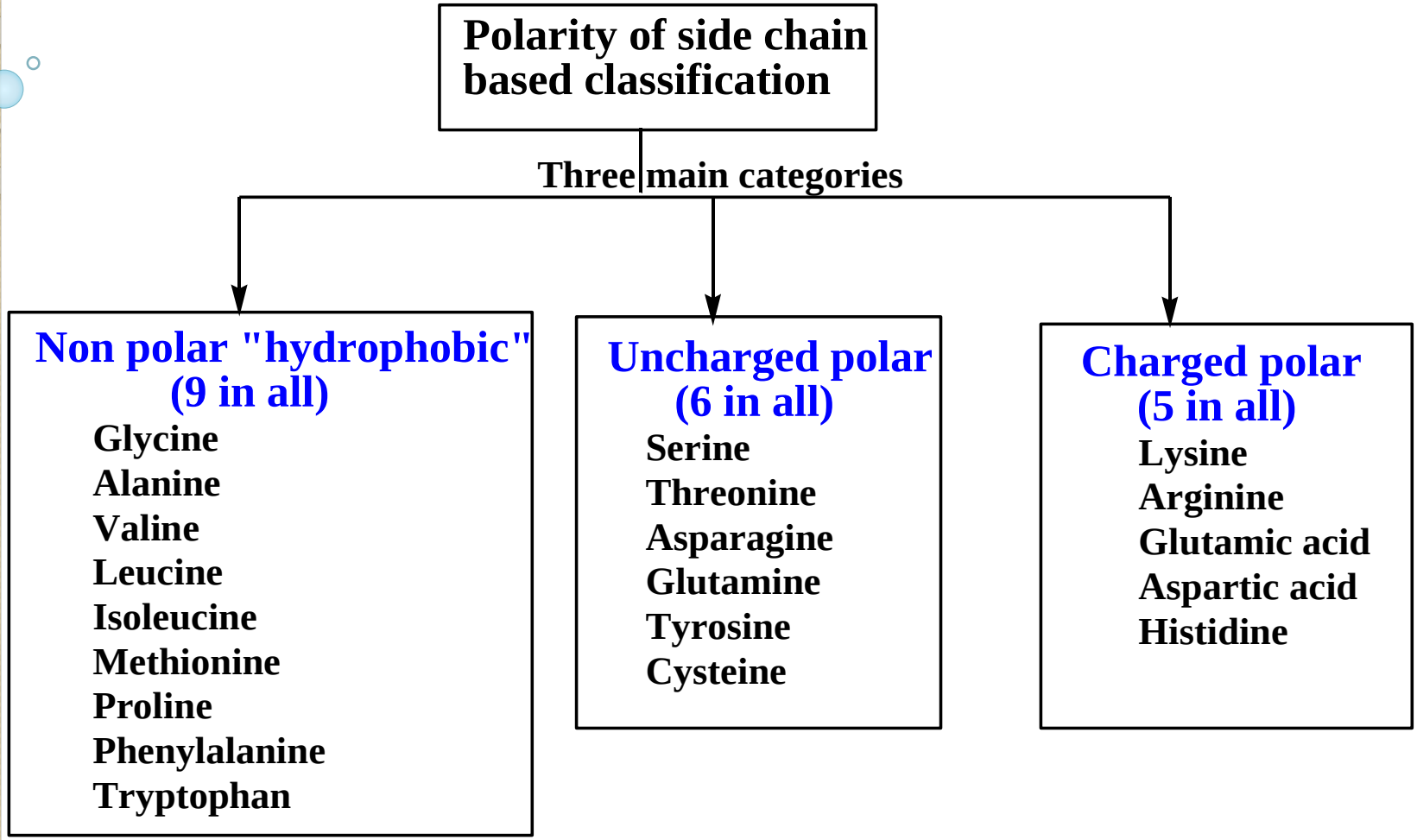
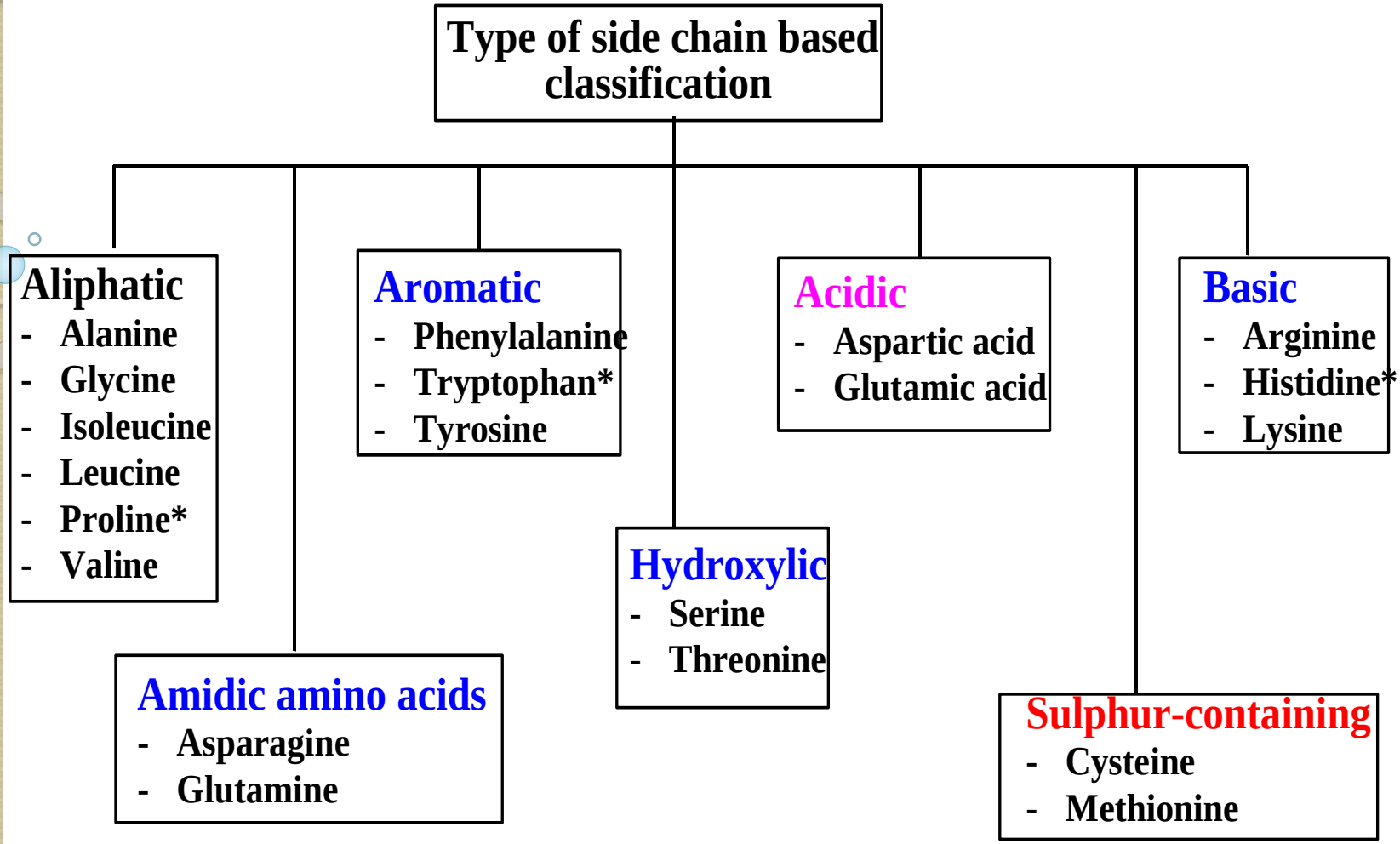


Figure 1.2: type of side chain (polarity) based classification

Protein amino acids cont.

1.2.2.4 Types of side chains: functional groups

- Depending on the functional groups, aas can be aliphatic, aromatic, acidic, basic, hydroxylic, sulphur containing or amidic (containing amide group) (fig 1.3)



*** proline, tryptophan and histidine are heterocyclic amino acids**

Figure 1.3: type of side chain (functional groups) based classification

Protein amino acids cont.

1.2.2.5 Essential amino acids

- All 20 of the aas are necessary for protein synthesis
- Humans can synthesize only 10 of the 20
- The other 10 must be obtained from food:
  - valine, leucine, isoleucine, phenylalanine, tryptophan, threonine, methionine, lysine, arginine and histidine

Protein amino acids cont.

1.2.3 Physical and chemical properties

- All the pure α-aas are colorless crystal, with quite high melting point (>200 ^{o}C) and water solubility
- **Solubility**: generally aas are-
  - ✓ soluble in water but
  - ✓ only slightly soluble in alcohol
- General test: is to warm with ninhydrin,
  - ✓ All except proline give a pink, blue or violet color
  - ✓ Proline gives a yellow color

Protein amino acids cont.

- **Spesific test:**
  - ✓Certain aas are detected by more specific tests
    - e.g. histidine gives color reactions with diazonium salts

Protein amino acids cont.

Acid–base properties of amino acids

- The neutral forms of amino acids are zwitterions.
- This is why
  - amino acids are insoluble in apolar aprotic solvents, e.g. ether, but most non-protonated amines and unionized carboxylic acids dissolve in ether.

Protein amino acids cont.

- The high mps and greater water solubility than in ether are salt like characteristics, not the characteristics of uncharged organic molecules.
- This salt like characteristic is found in all zwitterionic compounds.

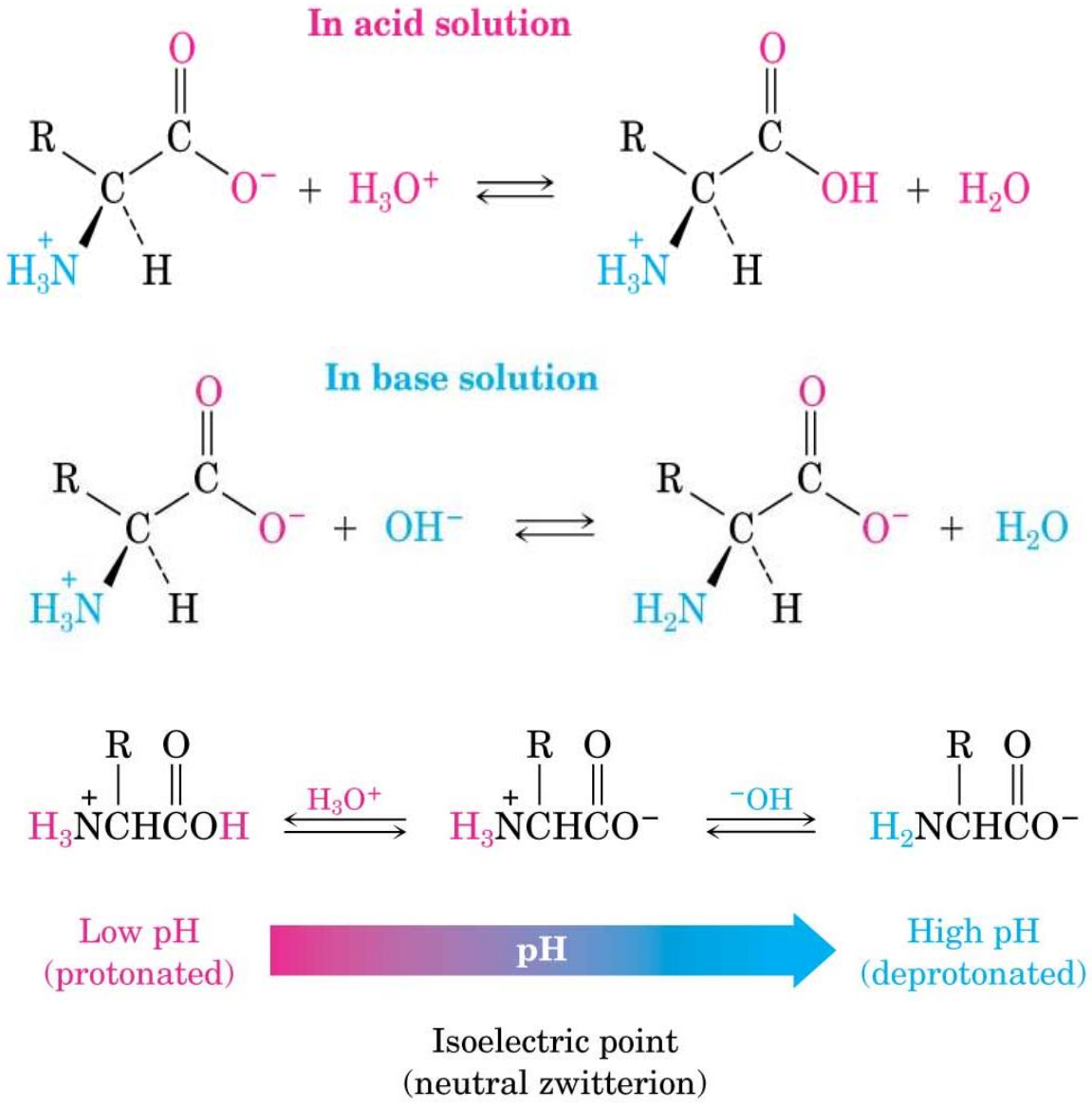
- Water is the best solvent for most aas b/c it solvates ionic groups much as it solvates the ions of a salt.

Protein amino acids cont.

Isoelectric points of amino acids and peptides

- In acidic solution,
  - the carboxylate and amine are in their conjugate acid forms, an overall cation
- In basic solution,
  - the groups are in their base forms, an overall anion
- In neutral solution,
  - cation and anion forms are present
  - This pH where the overall charge is 0 is the isoelectric point (pI) or isoelectric pH

Protein amino acids cont.



Properties and Conventions Associated with the Common Amino Acids Found in Proteins

Amino acid	Abbreviation/ symbol	M_r	pK_a values: pK_1 (—COOH)	pK_2 ($—NH_3^+$)	pK_R (R group)	pI
Nonpolar, aliphatic R groups						
Glycine	Gly G	75	2.34	9.60		5.97
Alanine	Ala A	89	2.34	9.69		6.01
Proline	Pro P	115	1.99	10.96		6.48
Valine	Val V	117	2.32	9.62		5.97
Leucine	Leu L	131	2.36	9.60		5.98
Isoleucine	Ile I	131	2.36	9.68		6.02
Methionine	Met M	149	2.28	9.21		5.74
Aromatic R groups						
Phenylalanine	Phe F	165	1.83	9.13		5.48
Tyrosine	Tyr Y	181	2.20	9.11	10.07	5.66
Tryptophan	Trp W	204	2.38	9.39		5.89

Properties and Conventions Associated with the Common Amino Acids Found in Proteins

Amino acid	Abbreviation/ symbol	M_r	pK_a values: pK_1 (—COOH)	pK_2 ($—NH_3^+$)	pK_R (R group)	pI
Polar, uncharged R groups						
Serine	Ser S	105	2.21	9.15		5.68
Threonine	Thr T	119	2.11	9.62		5.87
Cysteine	Cys C	121	1.96	10.28	8.18	5.07
Asparagine	Asn N	132	2.02	8.80		5.41
Glutamine	Gln Q	146	2.17	9.13		5.65
Positively charged R groups						
Lysine	Lys K	146	2.18	8.95	10.53	9.74
Histidine	His H	155	1.82	9.17	6.00	7.59
Arginine	Arg R	174	2.17	9.04	12.48	10.76
Negatively charged R groups						
Aspartate	Asp D	133	1.88	9.60	3.65	2.77
Glutamate	Glu E	147	2.19	9.67	4.25	3.22

Protein amino acids cont.

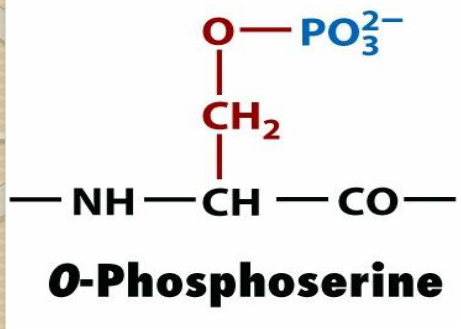
Reactions of Amino Acids

- Carboxyl groups form **amides** & **esters**
- Amino groups form **Schiff bases** and **amides**
- Side chains show unique reactivity
  - ✓ Cys residues can form disulfides and can be easily alkylated
  - ✓ Few reactions are specific to a single kind of side chain

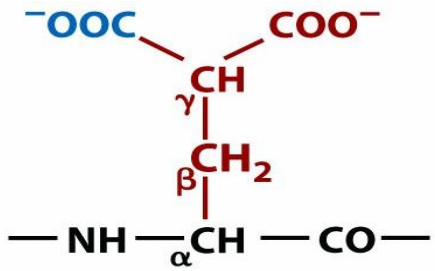
Protein amino acids cont.

- ✓ Here follows examples of side chain modifications
  - Disulfide Bond Formation (Cystine)
  - Hydroxylation (proline, lysine)
  - Phosphorylation (serine, histidine)
  - Acetylation (lysine)
  - Formylation (amino terminal methionine)
  - Other Modifications
    - Methylation (methyl group)
    - Glycosylation (sugar)

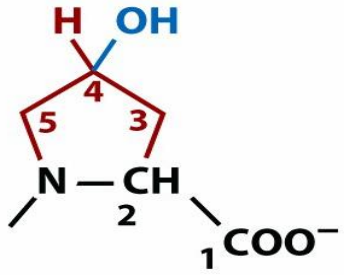
Protein amino acids cont.



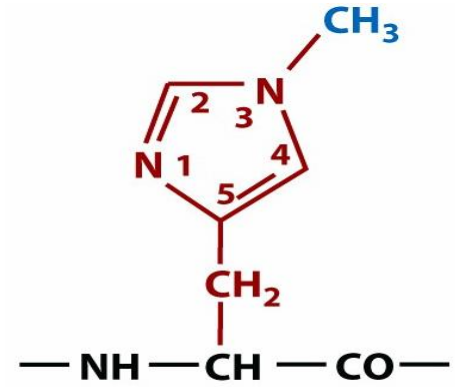
***O*-Phosphoserine**



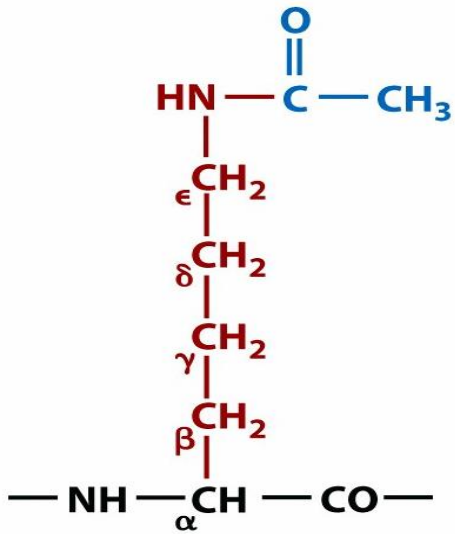
γ-Carboxyglutamate



4-Hydroxyproline



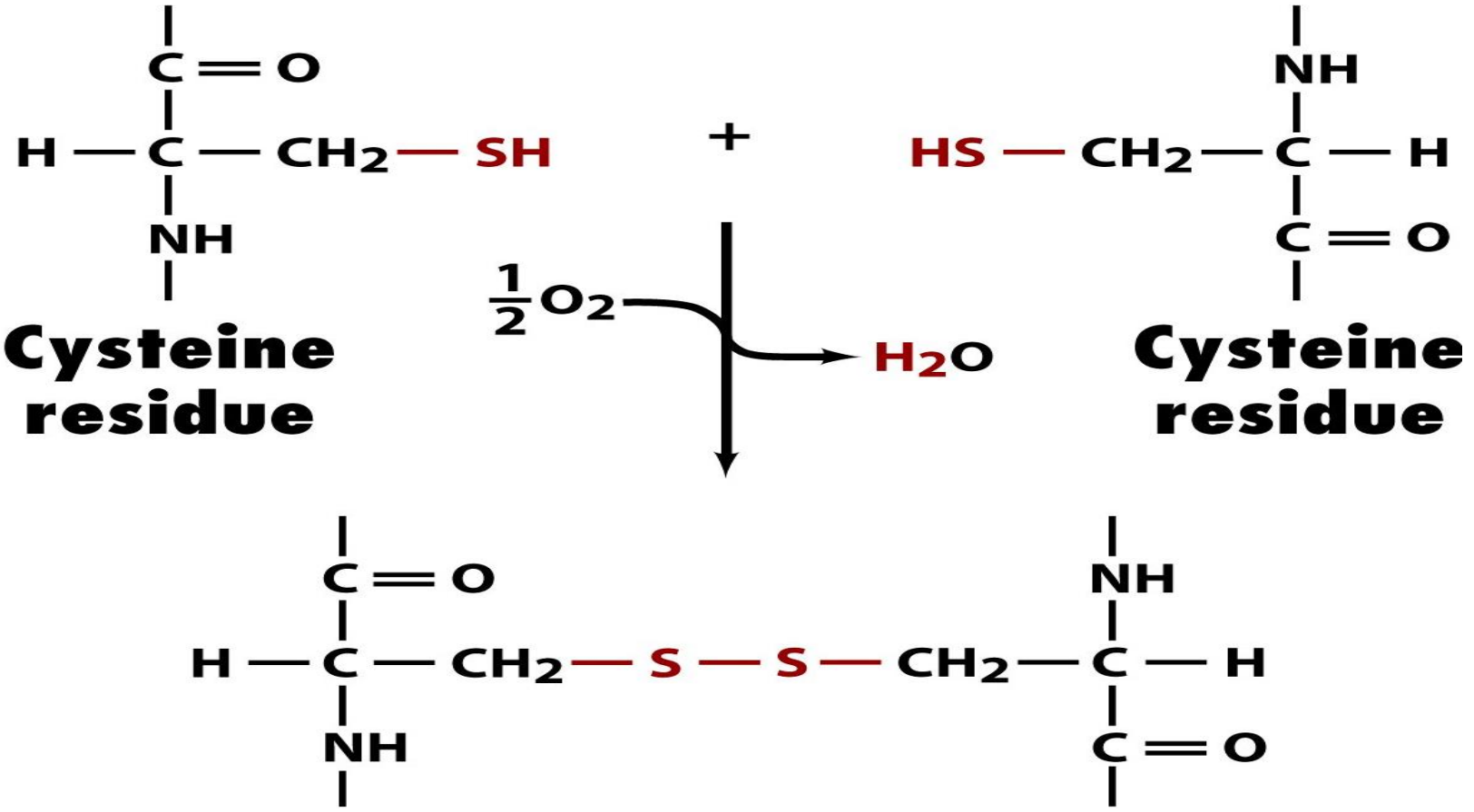
3-Methylhistidine



ε-*N*-Acetyllysine

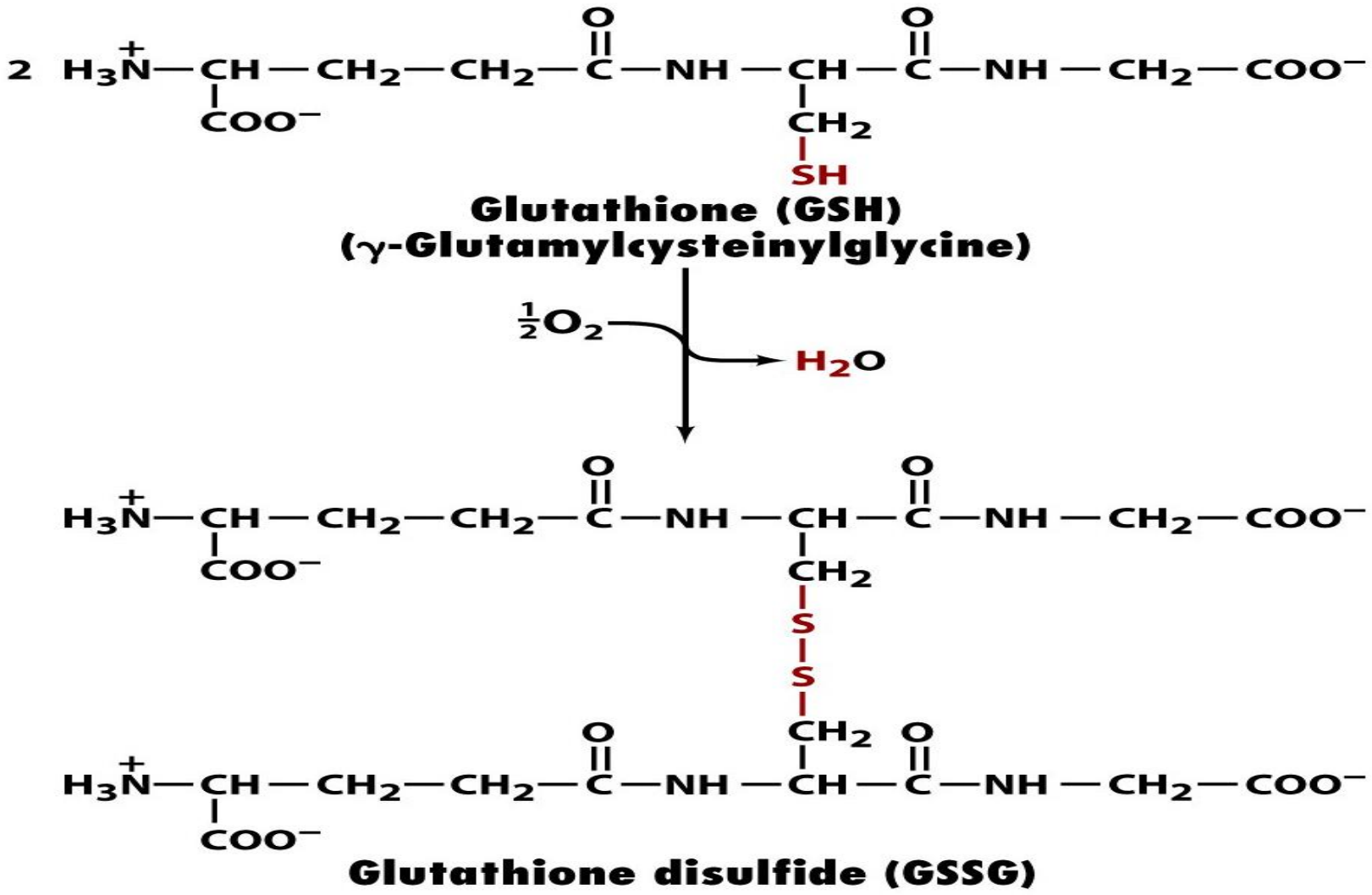
Examples of Side Chain Modifications in Proteins

Protein amino acids cont.



Cystine consists of two disulfide-linked cysteine residues

Protein amino acids cont.



Protein amino acids cont.

1.2.4 Stereochemistry of α-amino acids-chirality

- Most amino acids are optically active
- The α-carbon atoms of α-aas are chiral for all amino acids except for glycine.
  - Glycine, 2-amino-acetic acid, is achiral
  - In all the others, the α carbons of the aas are centers of chirality
- The stereochemical reference for amino acids is the Fischer projection of L-serine

Protein amino acids cont.

- **1.2.5 Spectroscopic Properties**
- All amino acids absorb in infrared region
- Only Phe, Tyr, and Trp absorb UV
- Absorbance at 280 nm is a good diagnostic device for amino acids
- NMR spectra are characteristic of each residue in a protein, and high resolution NMR measurements can be used to elucidate three-dimensional structures of proteins

Protein amino acids cont.

1.2.6 Significance of aas in human body

- In our bodies, amino acids are
  - Used for the synthesis of proteins and other nitrogen-containing compounds
  - Oxidized to produce energy.

Protein amino acids cont.

- Examples of amino-acid-derived nitrogen-containing biologically important group of compounds include:
  - Cellular proteins,
  - hormones (thyroxin, epinephrine and insulin),
  - neurotransmitters,
  - creatine phosphate,
  - the haem of haemoglobin,
  - cytochrome,
  - melanin (skin pigment) and
  - nucleic acid bases (purine and pyrimidine)

Protein amino acids cont.

1.2.7 Uncommon Amino Acids

- Hydroxylysine, hydroxyproline - collagen
- Carboxyglutamate - blood-clotting proteins
- Pyroglutamate - bacteriorhodopsin
- Phosphorylated amino acids - signaling device

1.3 Non-protein amino acids

- About **700** amino acids are known,
  - **at least 300 from plants**
  - Can be considered as secondary metabolites
  - Found mostly in a small number of families
    - ✓ Fabaceae or Leguminosae
    - ✓ seeds of Cucurbitaceae
    - ✓ Sapindaceae, Aceraceae, Hippocastanaceae

Non-protein aas cont.

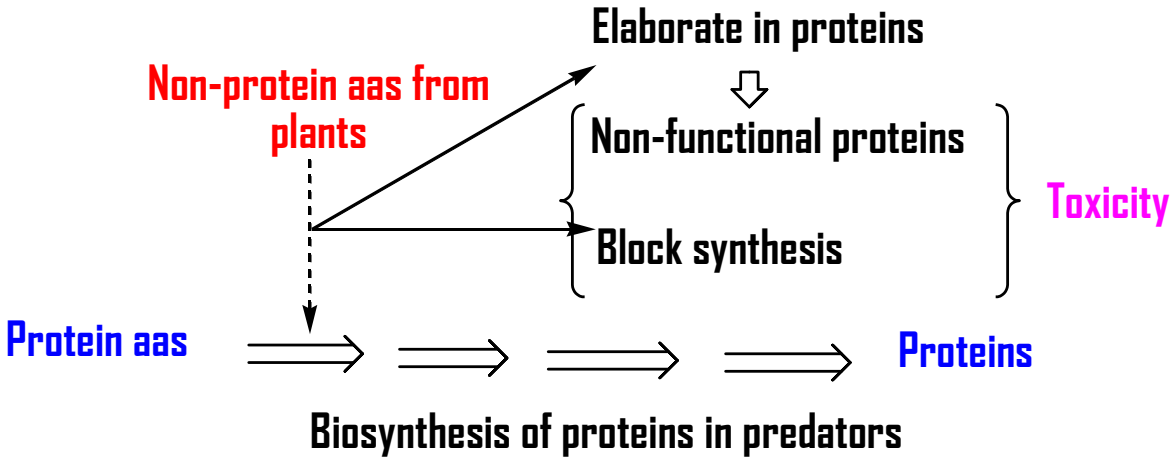
- Three major routes for origin
  a) Modification of existing (often protein) amino acid
  b) Modification of an existing pathway
  c) Novel pathways
- Several hundred of non-protein aas, but only a few are of wide occurrence:
  - e.g. γ -aminobutyric acid, α-aminoadipic acid, pipecolic acid and δ-acetylornithine

Non-protein aas cont.

- **Functions of non-protein aas**
  - Often as little known as those of most 2^{o} metabolites
  - Some are known to accumulate in the seeds of certain species and disappear during germination
    - My be considered to be **nitrogen storage**
  - In a number of cases, they participate in the maintenance and survival of the species:
    - e.g. **inhibit germination of foreign pollen on the style of the flower**

Non-protein aas cont.

- Many reveal their toxicity up on encounter with predators (fungai, microorganisms)
  - Anti-metabolic activity which is actually very general;
    - ✓ i.e interfere protein biosynthesis

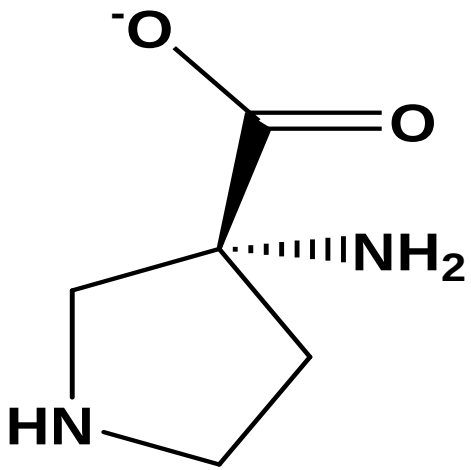


Non-protein aas cont.

- These aas are, in current state of knowledge, devoid of pharmacological interest, but
  - the **toxicity** of some of them for man and domestic animals deserves to be mentioned

Non-protein aas cont.

- Note
  - ✓ The teniacide properties of cucurbitine (3-amino-3-caboxypyrrolidine) explains the long time use of pumpkin seeds (*cucurbita pepo* L., cucurbitaceae) to treat "worms" in children



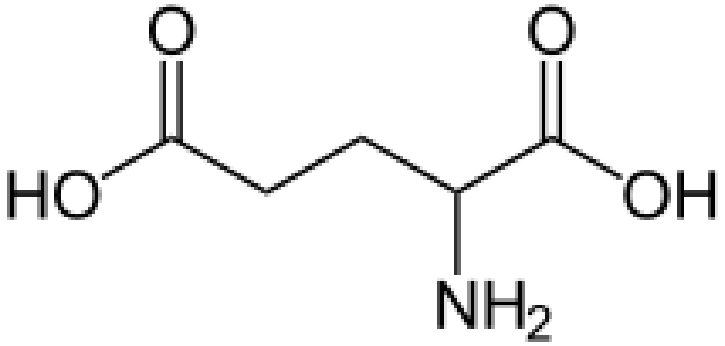
Cucurbitine

Non-protein aas cont.

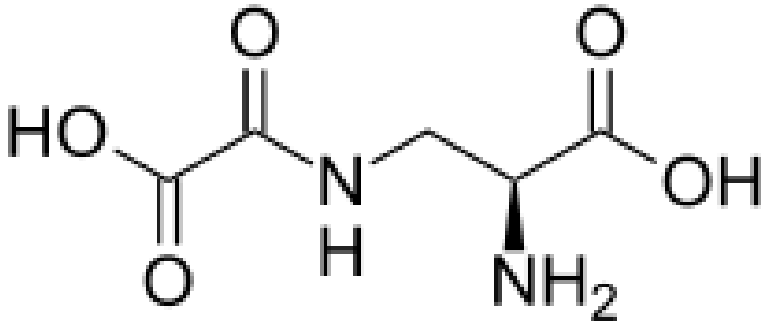
- Example of toxic aa containing plants
  - ***Lathyrus sativus*** = Sebere (Tya), guaya (Amh)
- **Cause**

a) Neurolathyrism: manifests as

- rigidity and a decrease in muscle strength of the legs,
- followed by progressive paralysis
  - linked to a spinal attack
- Responsible agent: ***Oxalyldiaminopropionic acid***



Glutamic acid



Oxalyldiaminopropionic acid

Non-protein aas cont.

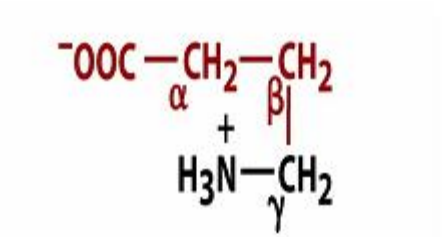
b) Oesteolathyrism, in animals: manifested as

- joint deformities, ligament separation, skeletal deformities and more

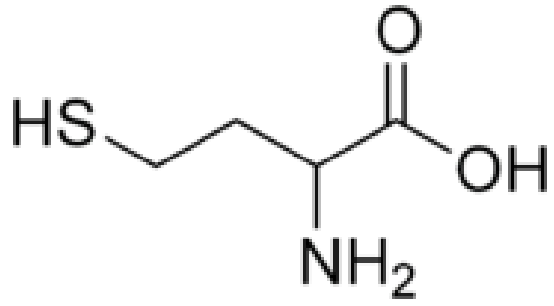
Non-protein aas cont.

- Examples of non-protein aas that are biologically important include:
  - Homocysteine $\Rightarrow$ linked to heart disease
  - γ-aminobutyric acid (GABA) $\Rightarrow$ neurotransmitter
  - Thyroxine $\Rightarrow$hormone in the thyroid gland

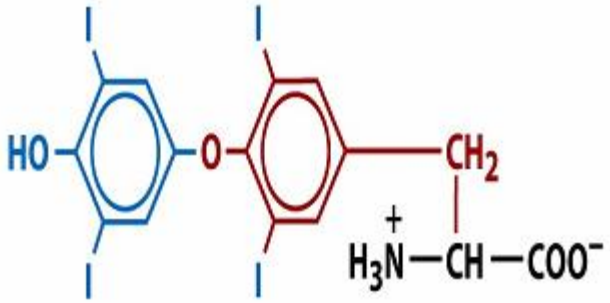
Non-protein aas cont.



γ-Aminobutyric acid (GABA)



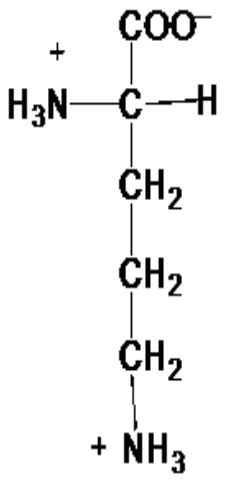
Homocysteine



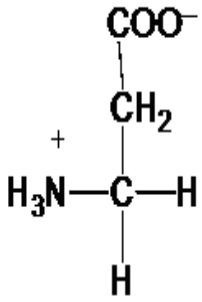
Thyroxine

Non-protein aas cont.

- Other non-protein aas and derivatives are: ⇒ Ornithine, β-Alanine, Histamine, Dopanine e.t.c

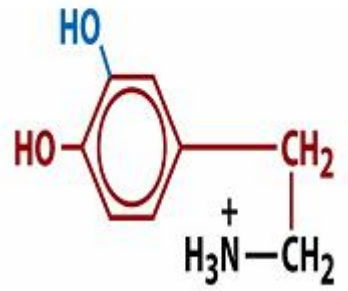


Ornithine



β-alanine

Histamine



Dopamine

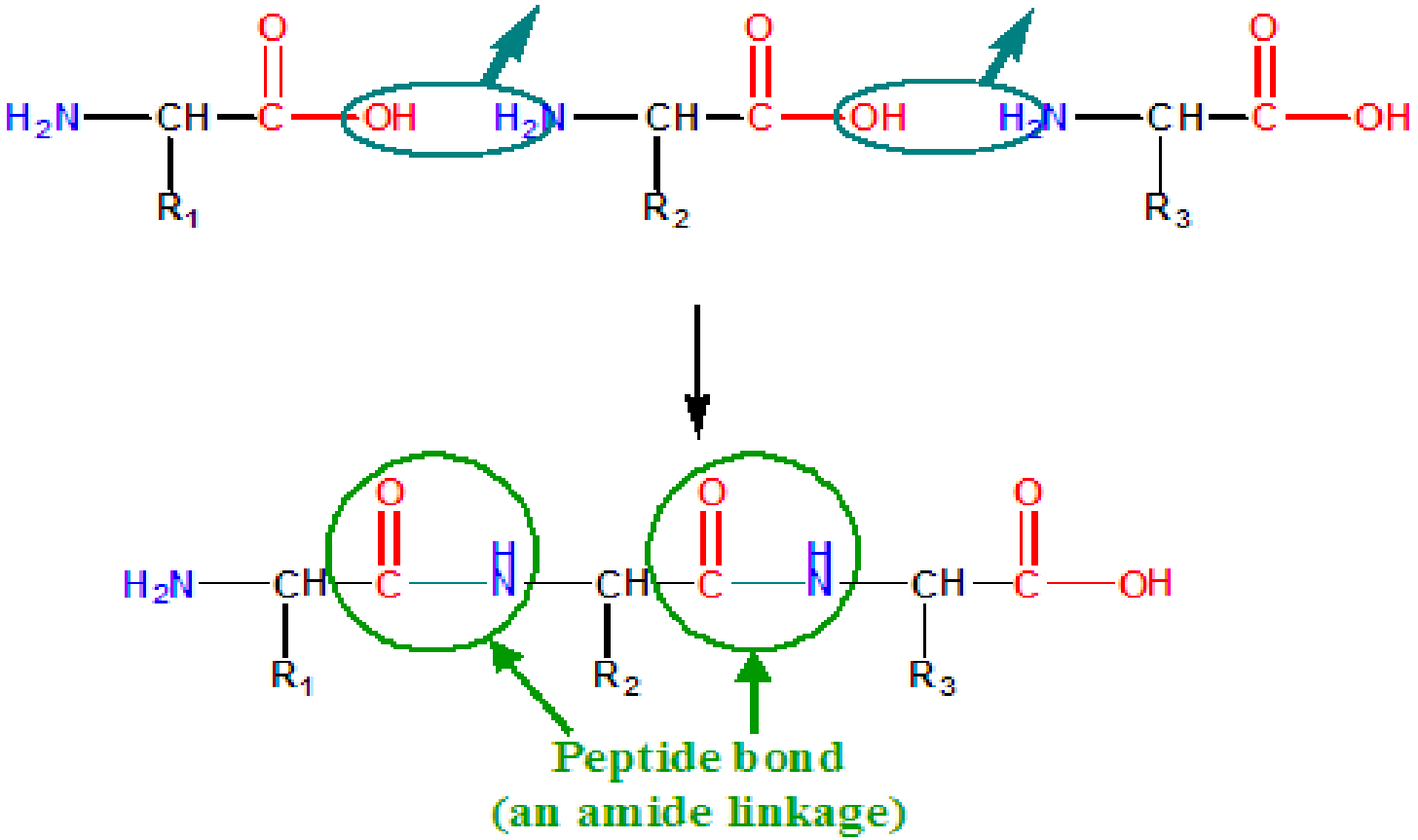
2. Peptides and proteins

2.1 Structure and nomenclature of peptides

A. Definition and structure of peptides

- Peptides are biological "polymers" which are made up of individual amino acid units.
- The linkage b/n aas in peptides is through an amide bond (biochemists call this “peptide bond”).
  - The amide bond is formed between
    - the –COOH end of one aa and
    - the $-NH_2$ group of another aa and
    - water is generated.

Peptides cont.



Peptides cont.

- When aas are linked together by amide linkages, the resulting molecule is called a *peptide*.
  - A peptide is a *polymer* formed from individual amino acid units.
  - Peptides are named according to the number of amino acids that are linked:
    1. dipeptide: two amino acids
    2. tripeptide: three amino acids
    3. tetrapeptide: four amino acids etc.

Peptides cont.

- The term *oligopeptide* refers an aa polymer with a moderate number of repeating amino acid units.

- When a peptide grows to a length of about 70 to 100 aa units, the molecule begins to coil onto itself and assume a particular *secondary structure*.

- At this point, we no longer refer to the molecule as a "peptide"; we begin to call it a *protein*.

Peptides cont.

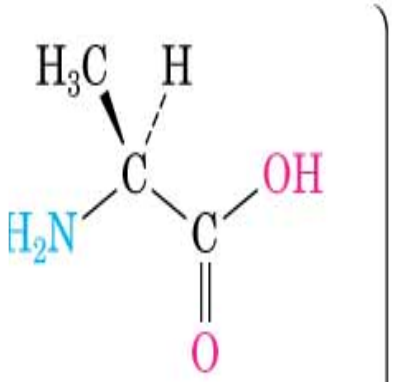
B Nomenclature of peptides

- The ends of a peptide are labeled as
  - **N-terminal**, the amino end or amino terminus
    - (the one with the free -NH_2 group)
  - **C-terminal**, the carboxy end or carboxy terminus
    - (the one with the free -CO_2H group)

Peptides cont.

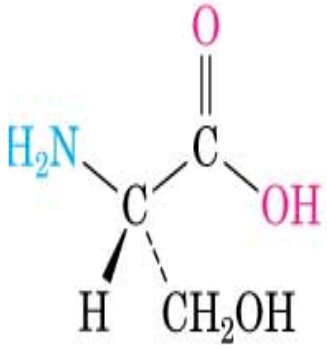
- Peptides are always written with
  - the N-terminal aa on the left and
  - the C-terminal aa on the right
- Instead of writing out complex formulae, sequences of aas are commonly written using the three- or one-letter codes e.g.
  - Alanyl-valyl-lysine is abbreviated as Ala–Val–Lys (3 letters) or AVK (one letter).
  - Alanyl-serine is abbreviated as Ala-Ser (or A-S), and
  - Seryl-alanine is abbreviated Ser-Ala (or S-A)

Peptides cont.

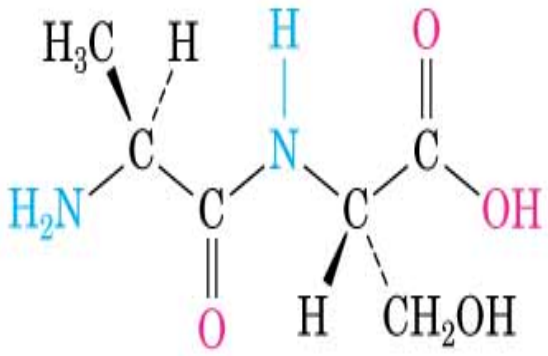


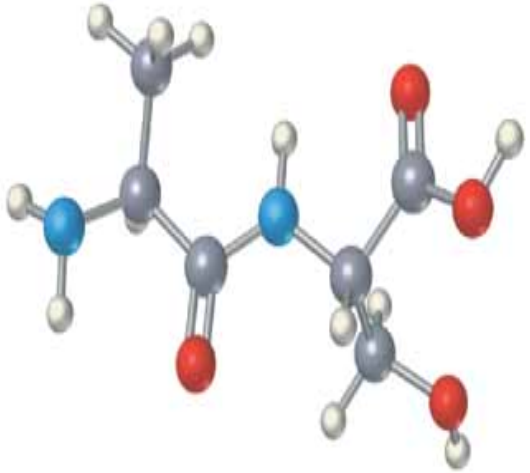
Alanine (Ala)

+



Serine (Ser)





Alanylserine (Ala-Ser)

Peptides cont.

- Large peptides of biological significance are known by their trivial names;
- e.g., insulin is an important peptide composed of 51 amino acid residues.

Peptides cont.

C. Nature of some bonds in peptides

- **Covalent Bonding in Peptides**
  - The amide bond in peptides is no different from any other amide bond.
  - Amide nitrogens are not basic because their unshared electron pair is delocalized by interaction with the carbonyl group.

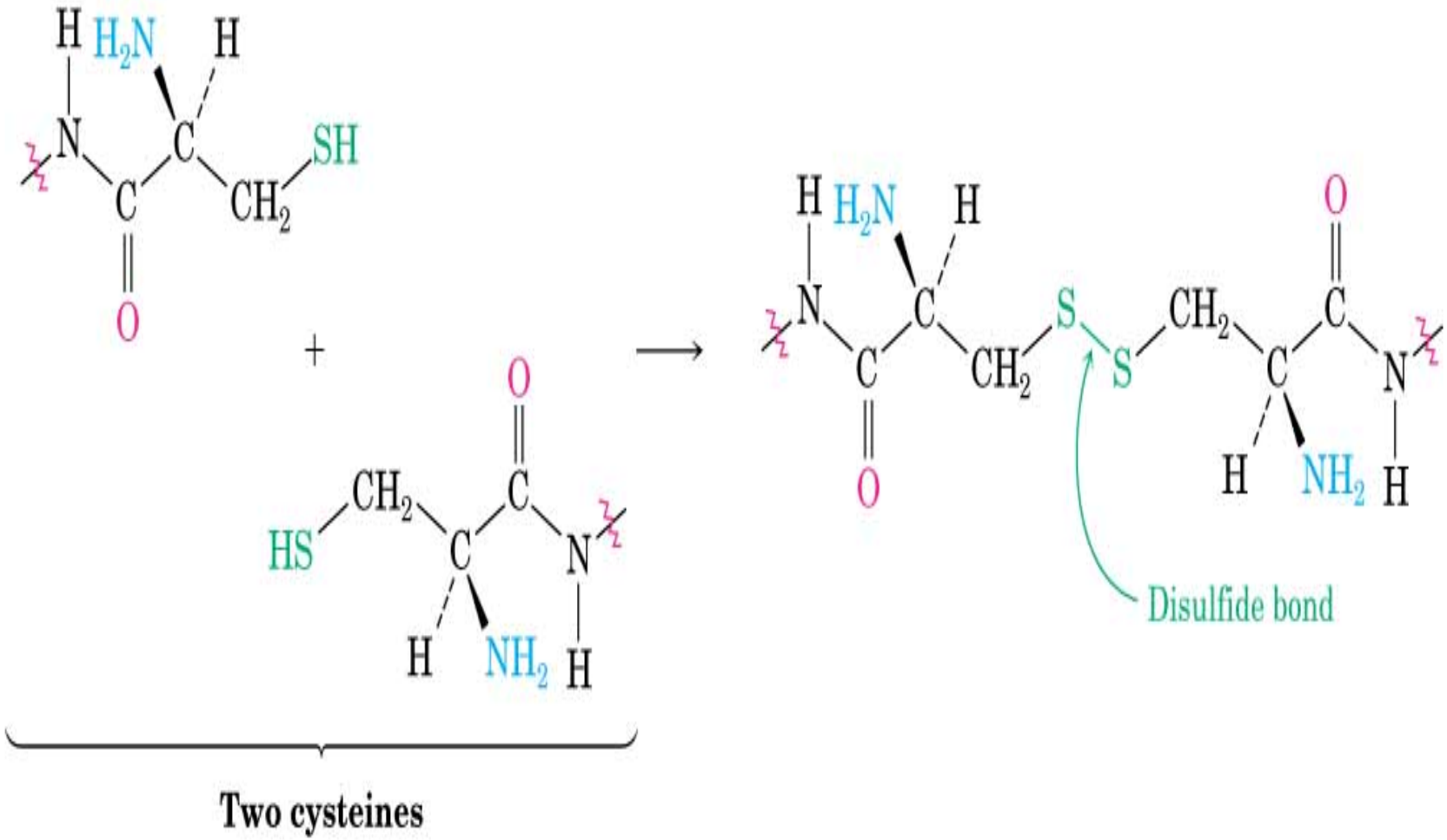
Peptides cont.

- This overlap of the nitrogen p orbital with the π orbitals of the carbonyl group imparts a certain amount of double-bond character to the C–N bond and restricts rotation around it.
- The amide bond is therefore planar, and the N–H is oriented 180° to the C=O.

Peptides cont.

- **Disulfides**
  - Thiols in adjacent chains can form a disulfide RS–SR through spontaneous oxidation
  - A disulfide bond between cysteine residues in different peptide chains links the otherwise separate chains together, while a disulfide bond between cysteine residues in the same chain forms a loop

Peptides cont.



Peptides cont.

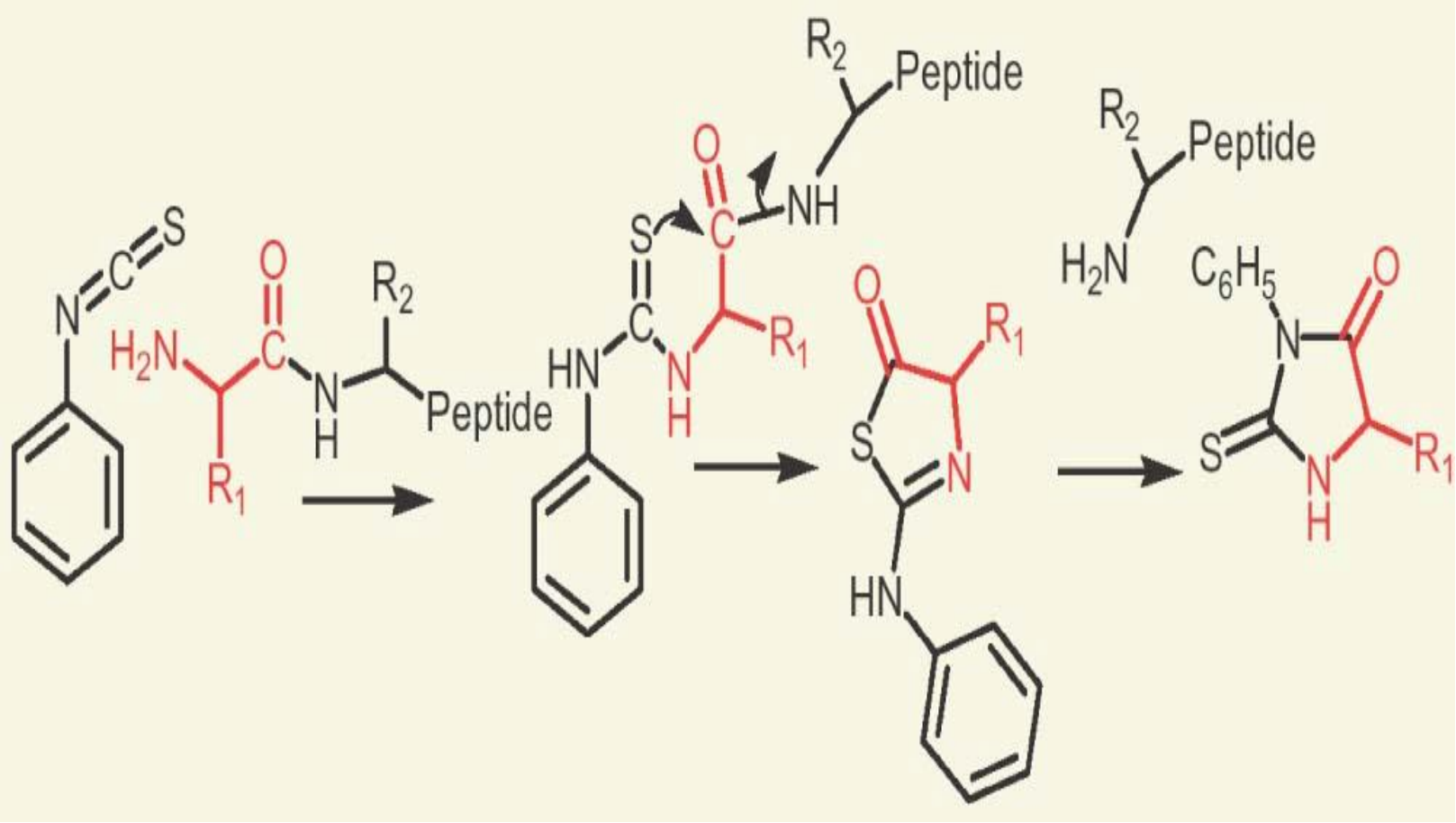
D. Structure Determination of Peptides: aa Analysis

- The sequence of aas in a pure protein is specified genetically
- If a protein is isolated it can be analyzed for its sequence
- The composition of aas can be obtained by automated chromatography and quantitative measurement of eluted materials using a reaction with ninhydrin that produces an intense purple color

Peptides cont.

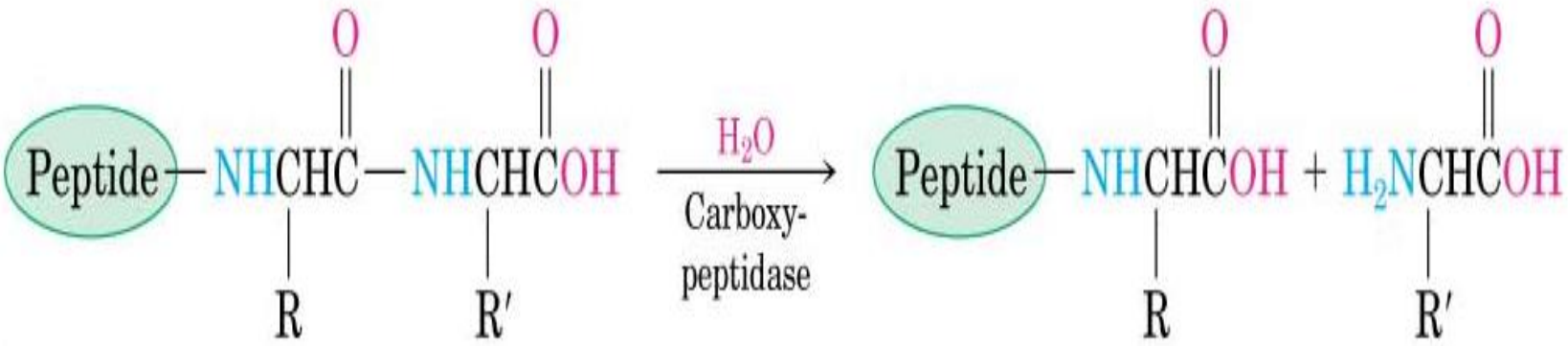
- **Peptide Sequencing: The Edman Degradation**
  - The Edman degradation cleaves amino acids one at a time from the N-terminus and forms a detectable, separable derivative for each amino acid
  - Phenyl isothiocyanate (PITC) is the coupling reagent

Peptides cont.



Peptides cont.

- **Peptide Sequencing: C-Terminal Residue Determination**
  - Carboxypeptidase enzymes cleave the C-terminal amide bond
  - Analysis determines the appearance of the first free amino acid, which must be at the carboxy terminus of the peptide

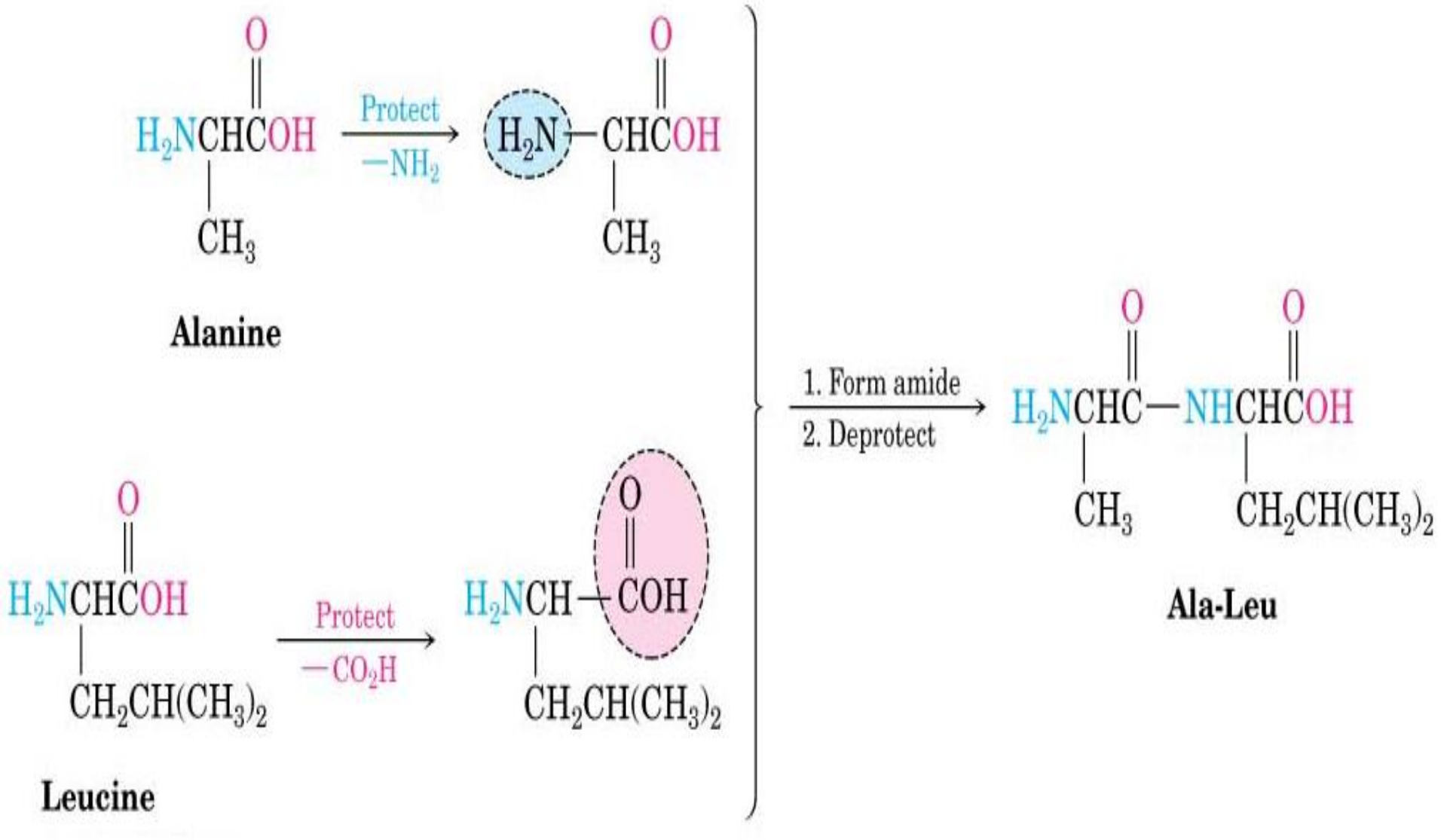


Peptides cont.

2.2 Synthesis of peptides

- Peptide synthesis requires that different amide bonds must be formed in a desired sequence
- The growing chain is protected at the carboxyl terminal and added amino acids are N-protected
- After peptide bond formation, N-protection is removed

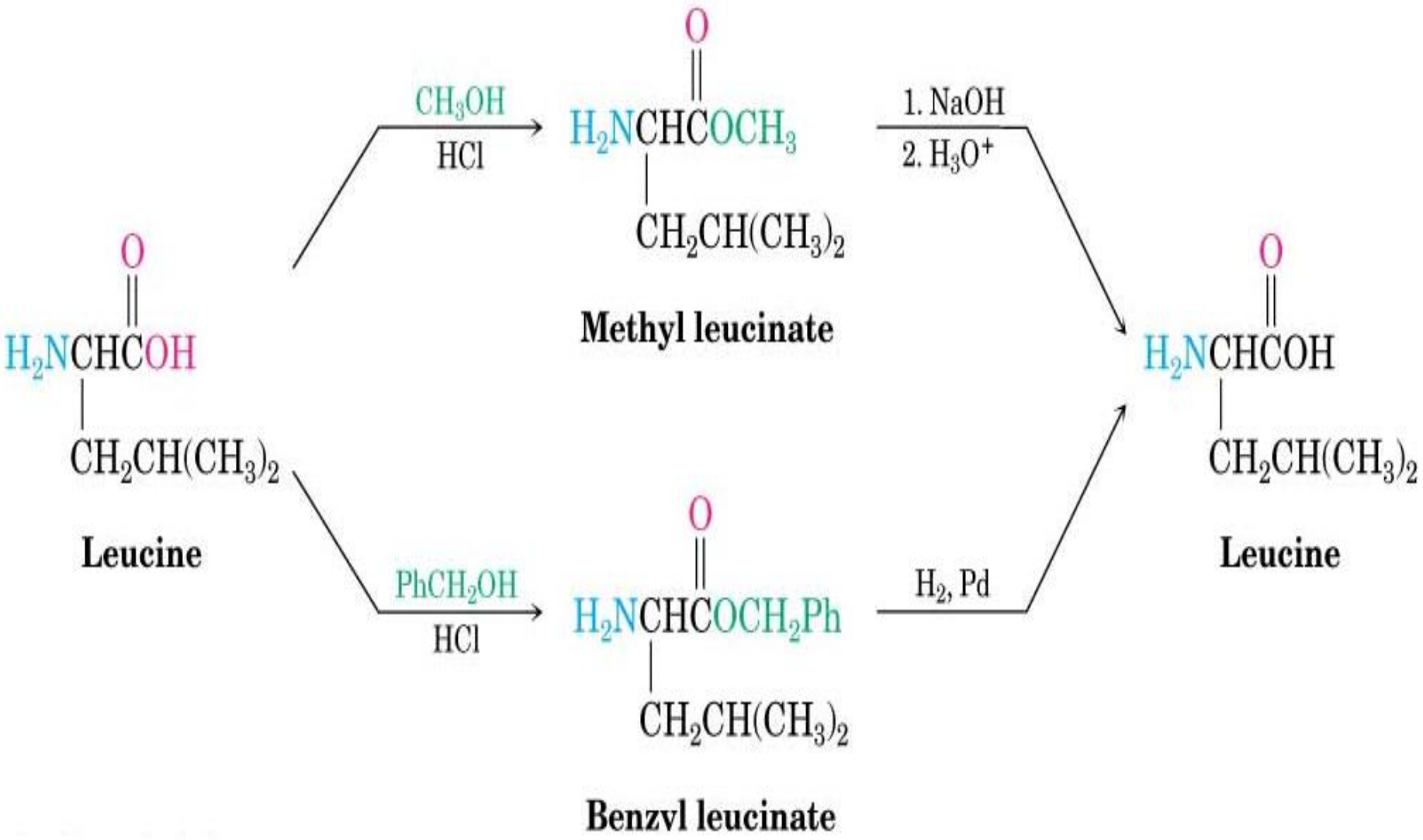
Peptides cont.



Peptides cont.

- **Carboxyl Protecting Groups**
  - Usually converted into methyl or benzyl esters
  - Removed by mild hydrolysis with aqueous NaOH
  - Benzyl esters are cleaved by catalytic hydrogenolysis of the weak benzylic C–O bond

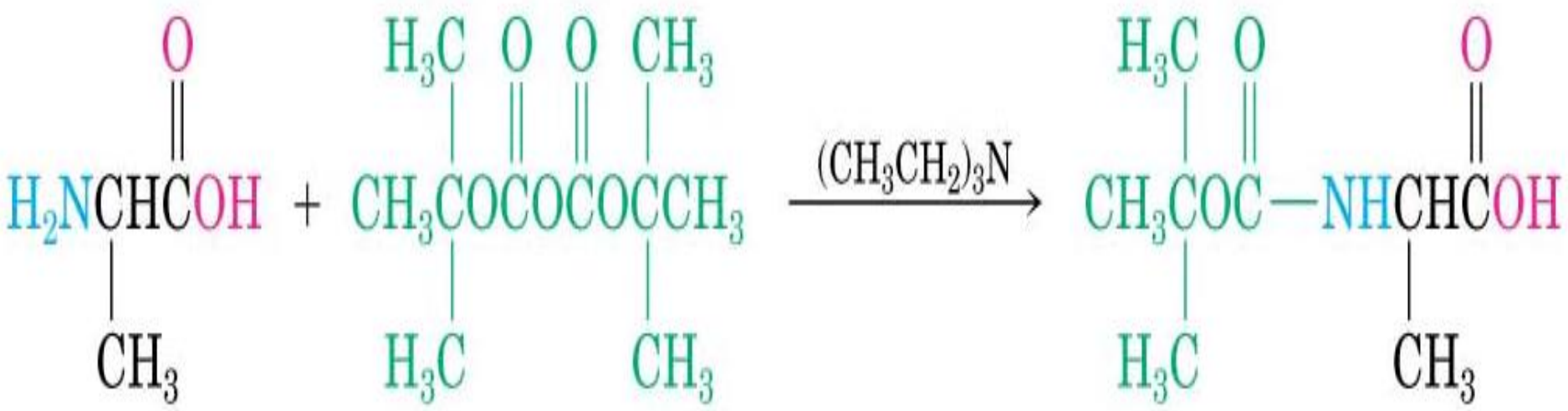
Peptides cont.



Peptides cont.

- **Amino Group Protection**
  - An amide that is less stable than the protein amide is formed and then removed
  - The tert-butoxycarbonyl amide (BOC) protecting group is introduced with di-tert-butyl dicarbonate
  - Removed by brief treatment with trifluoroacetic acid

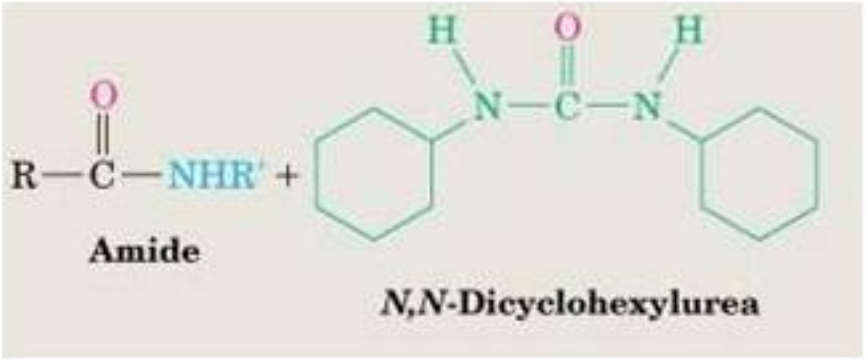
Peptides cont.

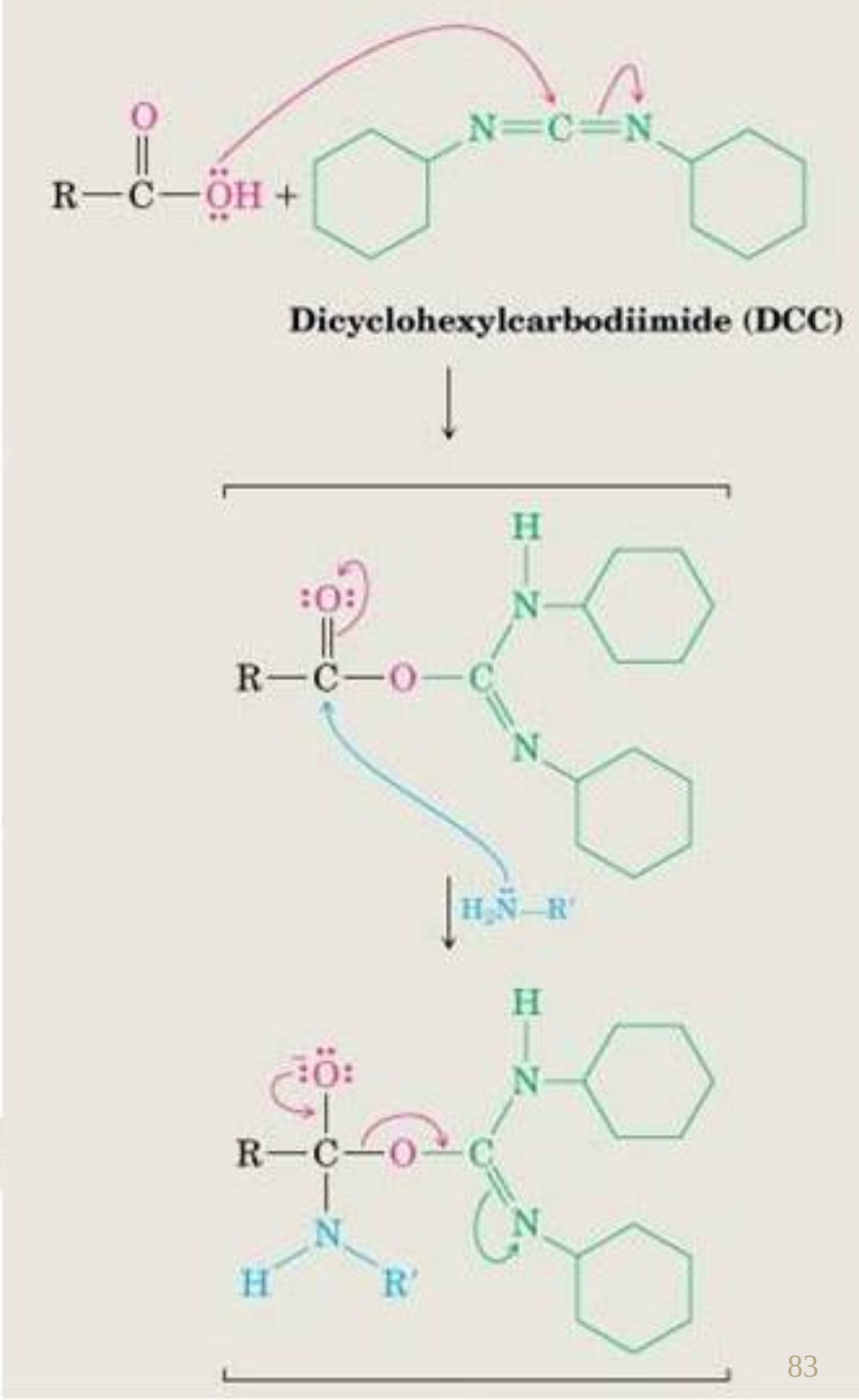


Alanine **Di-*tert*-butyl dicarbonate** **BOC-Ala**

Peptides cont.

- **Peptide Coupling**
  - Amides are formed by treating a mixture of an acid and amine with dicyclohexylcarbodiimide (DCC)


Amide
N,N-Dicyclohexylurea

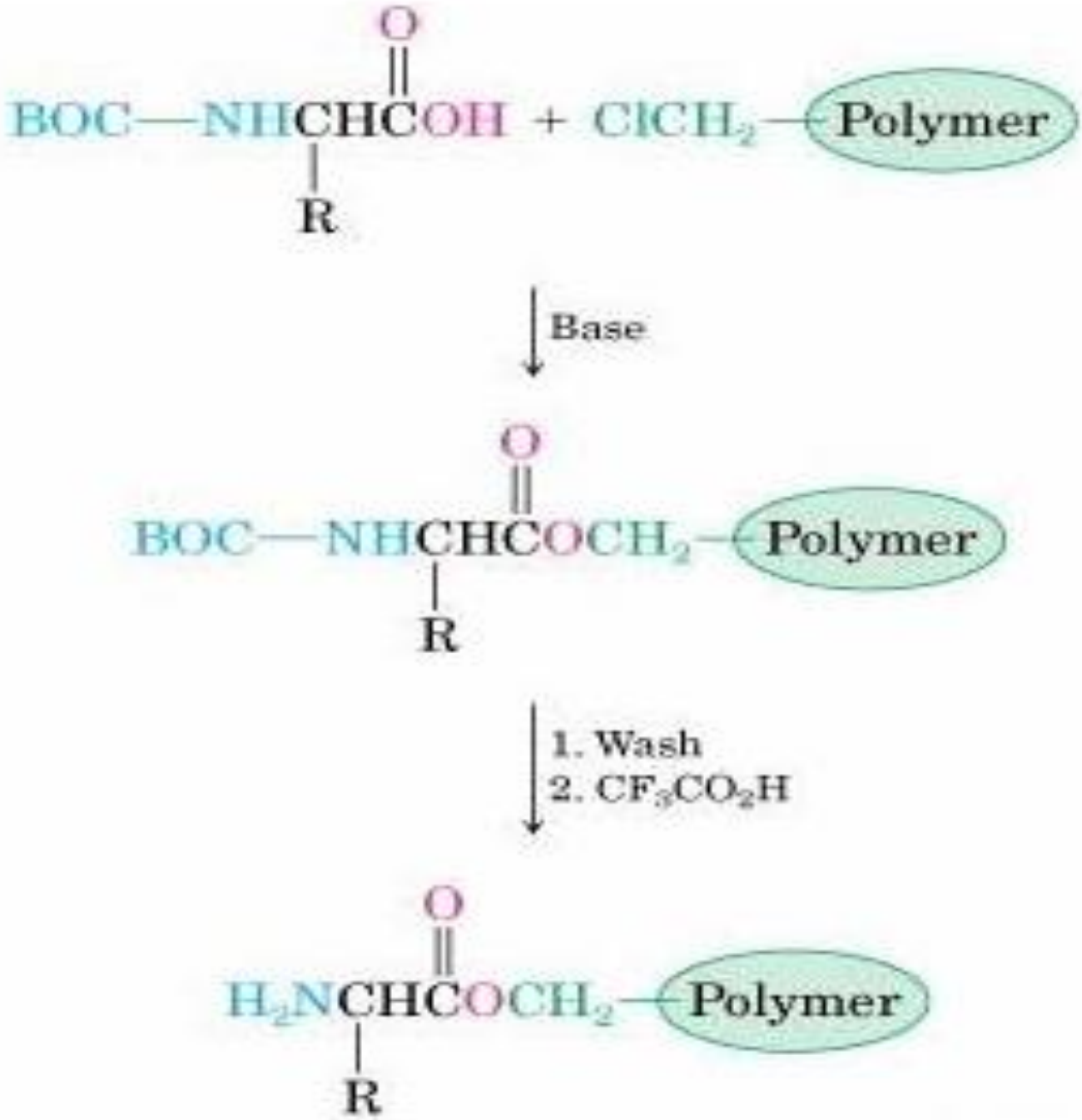

Dicyclohexylcarbodiimide (DCC)

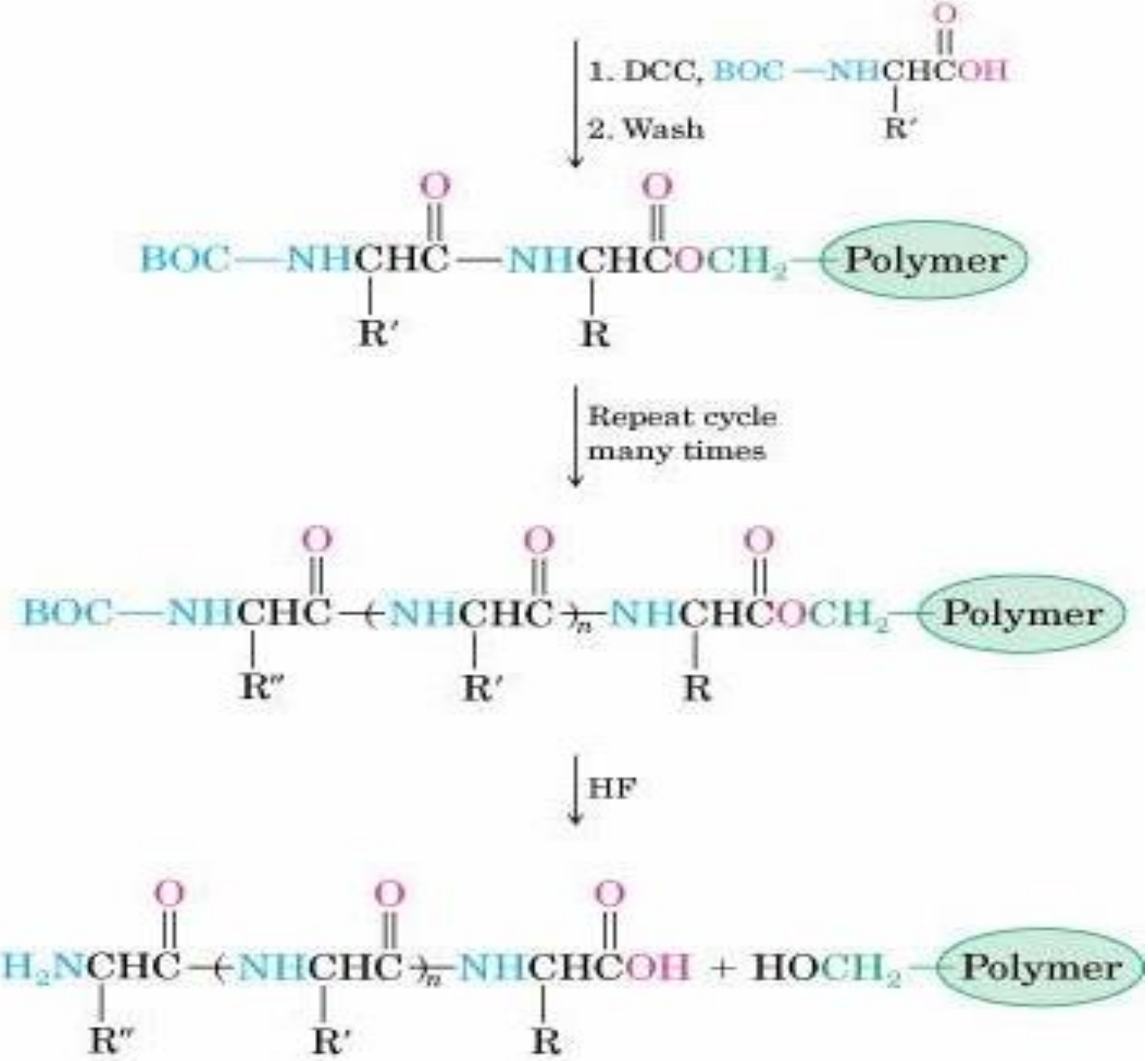
Peptides cont.

- **Automated Peptide Synthesis:**

The Merrifield Solid-Phase Technique

  - Peptides are connected to beads of polystyrene, reacted, cycled and cleaved at the end


BOC—NHCHCOH + ClCH2—Polymer
R
Base
BOC—NHCHCOCH2—Polymer
R
1. Wash
2. CF3CO2H
H2NCHCOCH2—Polymer
R


1. DCC, BOC—NHCHCOH
R′
2. Wash
BOC—NHCHC—NHCHCOCH2—Polymer
R′
R
Repeat cycle
many times
BOC—NHCHC—(NHCHC)n—NHCHCOCH2—Polymer
R″
R′
R
HF
H2NCHC—(NHCHC)n—NHCHCOH + HOCH2—Polymer
R″
R′
R

Peptides cont.

- **Automated Synthesis**
  - The solid-phase technique has been automated, and
  - computer-controlled peptide synthesizers are available for automatically repeating the coupling and deprotection steps with different amino acids

2.3 Structure and classification of proteins

A. Definition and structure of proteins

- **Proteins are large peptides.**
- Polypeptides involving more than about 100 amino acids are called **proteins**
- A protein is made up of one or more polypeptide chains
- The exact nature and function of proteins is determined by the aas present and the order they occur.

Proteins cont.

- Proteins have **four levels of structure** associated with them

a. Primary structure

  - Refers to the sequence in which aas are covalently bound to each other to form the protein.
  - It is the particular sequence of amino acids that is the backbone of a peptide chain or protein

Proteins cont.

b. Secondary structure

- ✓ Refers to the way the *segments* of a protein folds into a *regular pattern*, such as
  - o α-helix, Beta Pleated Sheet and Triple Helix
- ✓ **Alpha Helix**
  - ◦ Three-dimensional arrangement of aas with the polypeptide chain in a corkscrew shape

Proteins cont.

- Held by H bonds between the H of –N-H group and the –O of C=O of the fourth amino acid along the chain
- Looks like a coiled "telephone cord"
- Keratin has an α-helix

Proteins cont.

- **Beta Pleated Sheet**
  - Polypeptide chains are arranged side by side
  - Hydrogen bonds form between chains
  - R groups extend above and below the sheet
  - Typical of fibrous proteins such as silk

Proteins cont.

- **Triple Helix**
  - Three polypeptide chains woven together
  - H bonding between –OH groups gives a strong structure
  - Typical of collagen, connective tissue, skin, tendons, and cartilage

Proteins cont.

c. Tertiary structure

- ✓ Refers to how a protein's overall structure adopts a 3-dimensional shape.
  - It is specific overall shape of a protein
- ✓ A protein may have parts or segments with different 2° structures that together give rise to its overall 3° structure.

Proteins cont.

- **Internal and External Forces**
  - Acidic or basic amino acids with charged side chains congregate on the exterior of the protein where they can be solvated by water
  - Amino acids with neutral, non-polar side chains congregate on the hydrocarbon-like interior of a protein molecule

Proteins cont.

- Also important for stabilizing a protein's tertiary structure are the formation of different cross links between R groups of amino acids in chain:
  - disulfide –S–S–
  - ionic –COO– H_3N^+–
  - H bonds –C=O HO–
  - hydrophobic –CH3 H3C–

Proteins cont.

d. Quarternary structure

- ✓ Refers to how different protein molecules interact to form aggregates.
- ✓ Contain proteins with two or more chains
- ✓ Example is hemoglobin
  - Carries oxygen in blood
  - Four polypeptide chains
  - Each chain has a heme group to bind oxygen

Proteins cont.

B. CLASSIFICATION OF PROTEINS

1. Classification based on composition

a. Simple proteins

- are made up of only amino acids
- yield only amino acids on hydrolysis

Proteins cont.

b. Conjugated proteins

- are made up of aas that may be linked to other biomolecules
- yield other compounds such as carbohydrates, fats, or nucleic acids in addition to aas on hydrolysis.
- are much more common than simple proteins

Proteins cont.

2. Classification based on 3D shape

a. Fibrous proteins

- consist of polypeptide chains arranged side by side in long filaments
- are long filaments that are water insoluble (Structural)

Proteins cont.

- **Globular proteins**
  - are coiled into spheres and are generally water soluble. (Enzymes)
  - are coiled into compact, roughly spherical shapes
  - Most enzymes are globular proteins

Proteins cont.

Name	Occurrence and use
Fibrous proteins (insoluble)	
Collagens	Animal hide, tendons, connective tissues
Elastins	Blood vessels, ligaments
Fibrinogen	Necessary for blood clotting
Keratins	Skin, wool, feathers, hooves, silk, fingernails
Myosins	Muscle tissue
Globular proteins (soluble)	
Hemoglobin	Involved in oxygen transport
Immunoglobulins	Involved in immune response
Insulin	Hormone for controlling glucose metabolism
Ribonuclease	Enzyme for controlling RNA synthesis

Proteins cont.

C. Protein hydrolysis and denaturation

❖ Protein Hydrolysis

- Break down of peptide bonds
- Requires acid or base, water and heat
- Gives smaller peptides and amino acids
- Similar to digestion of proteins using enzymes
- Occurs in cells to provide amino acids to synthesize other proteins and tissues

Proteins cont.

❖ Protein Denaturation

- Denaturation is disruption of secondary, tertiary and quaternary protein structure.
- The disruption can be by
  - Heat/organics
    - Break apart H bonds and disrupt hydrophobic attractions

Proteins cont.

- Acids/ bases
  - Break H bonds between polar R groups and ionic bonds
- Heavy metal ions
  - React with S-S bonds to form solids
- Agitation
  - Stretches chains until bonds break

Proteins cont.

❖Applications of Denaturation

- Solubility is drastically decreased as in heating egg white, where the albumins unfold and coagulate
- Wiping the skin with alcohol swab for injection
- Cooking food to destroy *E. coli.*

Proteins cont.

- Heat used to cauterize blood vessels
- Autoclave sterilizes instruments
- Milk is heated to make yogurt
- Enzymes also lose all catalytic activity when denatured

End of topic